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# THESIS

## EVALUATION OF FACTORS AFFECTING REPEATABILITY AND ACCURACY OF TURBINE RIG TEST RESULTS

by

Terry Paul Eargle

June 1980

Thesis Advisor: R. Shreeve

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theoretical estimates, it was concluded that with normal atmospheric humidity supply temperatures close to 700°R were necessary to eliminate the influence of water condensation on blade row performance measurements, since the stator nozzles were supersonic. A detailed uncertainty analysis was carried out which successfully isolated the major causes of inaccuracies in loss data derived from rig measurements. Recommendations were made which, if followed, should result in repeatable and accurate measurements of blade row losses.

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# Evaluation of Factors Affecting Repeatability and Accuracy of Turbine Rig Test Results

by

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Lieutenant Commander, United States Navy
M.S., University of South Carolina, 1967

Submitted in partial fulfillment of the
requirements for the degrees

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# ABSTRACT

An experimental study was carried out to resolve anomalies and to determine the sources of inaccuracies which had hitherto been present in results from the Turbine Test Rig at the NPS Turbopropulsion Laboratory. Internal modifications to the rig's waterbrake dynamometer are reported which improved the RPM control everywhere but in the range 17,000 - 18,500 RPM. From an analysis of test results and theoretical estimates, it was concluded that with normal atmospheric humidity supply temperatures close to 700°R were necessary to eliminate the influence of water condensation on blade row performance measurements, since the stator nozzles were supersonic. A detailed uncertainty analysis was carried out which successfully isolated the major causes of inaccuracies in loss data derived from rig measurements. Recommendations were made which, if followed, should result in repeatable and accurate measurements of blade row losses.

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# LIST OF SYMBOLS

| | |
|---|---|
| P | Pressure |
| T | Temperature |
| RAF | Resultant Axial Force |
| AXF | Axial Force (Capsule) |
| CLF | Closure Force (Capsule) |
| STM | Stator Torque (Moment) |
| RTM | Rotor Torque (Moment) |
| $\dot{W}$ | Air Flow Rate |
| PR | Pressure Ratio |

## Subscripts

| | |
|---|---|
| t | Total Condition |
| ref | Referred |

## Greek Letters

| | |
|---|---|
| $\zeta$ | Loss Coefficient |

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# I. INTRODUCTION

An investigation of the performance of a turbine stage when the rotor to stator axial spacing was varied in a systematic way was carried out by Kane and reported in Reference 1. The data on maximum efficiency vs. axial spacing obtained by Kane [Fig. 21, Ref. 1], was not sufficient to determine an optimum spacing because the minimum clearance was physically limited to 0.244 in. Therefore a recommendation was made in Ref. 1 to conduct further testing by modifying the rotor to allow a closer axial spacing. The original purpose in the current investigation was to conduct the recommended tests. A second purpose was to investigate ways to make the current rig/waterbrake system more stable.

At the outset, significant revisions were required in the data acquisition programs to bring all data acquisition online for the first time. A first test was then conducted to checkout the rig and data acquisition system by attempting to duplicate run 7 of Ref. 1. Significant differences were noted in the interstage pressure ratios and the stator and rotor loss coefficients evaluated from the new data. In the attempt to resolve these differences, further tests were carried out which showed that the turbine stagnation temperature had a measurable effect on the pressure levels (when properly non-dimensionalised) throughout the blading, whereas stagnation pressure had no measurable effect. It was also

evident in the early tests, that the speed fluctuations were much higher than the uncertainty interval (±175 RPM) reported in Ref. 1.

The goal of the present study was to resolve the observed anomalies, and to obtain an understanding of the parameters affecting the accuracy of the data obtained from the rig. Three questions were addressed in the experimental program:

(i) What was the status of the speed control using the current waterbrake and controller, and could it be improved?

(ii) What was the cause of the observed effect of stagnation temperature?

(iii) What was the effect of the uncertainties in the measurements on the accuracy and repeatability of data derived from the rig?

The results of the investigation and responses to the above questions are contained in the main body of the report. Section II describes the test apparatus and associated instrumentation, the data reduction procedures and test program, and gives an account of the procedures followed in each test run. Section III documents the results of the investigation which are discussed in Section IV. Conclusions and recommendations are contained in Sections V and VI, respectively. A detailed calculation of the uncertainties in parameters evaluated from the rig measurements is given in Appendix C. These calculations were important in that they illustrated clearly which measured parameters govern the accuracy of data obtained from the turbine test rig.

# II. TEST APPARATUS AND PROCEDURES

## A. TEST EQUIPMENT

Figures 1, 2, and 3 show the test rig installation. Air to drive the turbine was provided by an Allis-Chalmers twelve stage axial compressor supplying pressure ratios of 3 to 1. Pressure ratios of 4 to 1 were obtained (6 to 1 is available) across the turbine by sealing the turbine in the hood and actuating the exhauster assembly shown in Figure 1. The exhauster assembly was an air ejector supplied from the Allis-Chalmers compressor. The exhauster reduced the pressure in the test hood to as low as half an atmosphere. Descriptions of the turbine test rig and associated instrumentation are given in Refs. 2-9.

The geometry of the stage blading is contained in Ref. 1. The different axial spacings possible with current hardware are shown in Figure 4. All tests in this investigation were run in position 1. The waterbrake reported in Ref. 1 was modified twice during the course of the present investigation. First one "slinger", and then a second, was added to attempt to attain more constant speeds. Figure 5a shows a side view of the dynamometer water wheel with two "slingers" installed. A close-up view of the water wheel with "slinger" installed is shown in Figure 5b. Prior to installation of the slingers, the water level in the dynamometer cavity would occasionally "collapse" inward, create a back

pressure, and cause a surge in RPM. The slingers were designed to prevent the water from "collapsing" inward.

## B. TEST INSTRUMENTATION

A schematic of the system used to acquire the data is shown in Figure 6. The addition of the HG-78K scanivalve controller allowed the punched paper tape system used previously, to be eliminated and provided complete on-line data acquisition and storage for the first time. A total of 60 measurements were taken at each data point. Pressure measurements were taken using a 48 port Scanivalve. Fourteen other transducers were scanned for measurements of temperature, force, torque, and differential pressures. RPM was measured using an HP-5328A Universal counter. All measurements except RPM were made using an HP-3455A Digital Voltmeter. The counter and voltmeter readings were then channelled through an HP-3495A scanner to the HP-9830A computer and subsequently stored on a mass memory platter. The instruments and the computer were connected via the HP "interface bus" (HP-IB).

## C. DATA ACQUISITION AND REDUCTION

Extensive modifications were required to the existing programs for data acquisition and reduction. A complete account of the modifications, descriptions of new software and current program listings are given in Appendix A.

The following changes and additions were made:

i) The data acquisition program was modified to incorporate on-line acquisition of Scanivalve and RPM data.

ii) The reduction programs developed by Solms [Ref. 7], Robbins [Ref. 8] and Boatright [Ref. 9] were modified.

iii) Software to sample, store and plot the RPM was generated.

iv) Software to determine the number of samples required to be taken of forces and torques was generated.

v) Program "UNCERT" was written to compute the uncertainties in the interstage conditions and loss coefficients evaluated from measurements.

## D. TEST PROGRAM

A list of the tests conducted is shown in Table I. Three series of tests were conducted, not always in sequential order, for the following purposes:

1. To determine the number of samples required to produce a constant average in the data values from selected non-pressure channels.
2. To evaluate RPM stability at various RPM's.
3. To evaluate test rig performance at different RPM's, pressure ratios, and temperatures.

The first test series was conducted at a P.R. = 3.0 and 11500 RPM. The second and third series were conducted at a variety of RPM's and pressure ratios.

At the beginning of each test, the pressure transducer in the Scanivalve and the differential transducer for the flow nozzle were calibrated using an air source and mercury monometer. The force and torque transducers were calibrated

by applying weights and adjusting the zero and range on the signal conditioning units to give a digital output in engineering units. Using the HP9830A program "SCAMOD", given in Appendix A, data for a particular point on a given test was automatically scanned and stored. Average acquisition time took 1 minute for a turbine performance point or 65 sec. for RPM sampling. Each data point gathered on turbine performance was reduced immediately to determine if any obvious errors existed before taking the next point. At the end of the run, all turbine performance points were tabulated by batch processing.

The performance tests were conducted holding stage pressure ratio constant. This was usually done by holding $P_{t_o}$ at a desired level and varying hood (back) pressure to obtain variations in the pressure ratio. However, in run 11, hood pressure was maintained at a constant level and $P_{t_o}$ was raised to evaluate what effects, if any, changing stagnation pressure had on the results at constant pressure ratio. When temperature effects were being evaluated, temperature was varied by closing off all, or a portion of, the water flow to the aftercooler and allowing the new temperature to stabilize. A change in total temperature, $T_{t_o}$, of no more than one degree in five minutes was taken to indicate that conditions had stabilizied. Tests to evaluate the RPM stability involved taking RPM samples at a variety of RPM settings. Each "sampling" consisted of 360 points gathered over a time interval of 65 sec. The data were plotted and stored.

## E. DATA STORAGE

A list of the raw data parameters recorded for the performance tests and scaling factors applied to each is contained in Appendix B. Several channels were averaged after repetitive sampling to improve accuracy, and these are also noted in Appendix B. A list of tests conducted and files and record numbers where raw and reduced data are stored is given in Table II. Table A-XV contains a list of data reduction plot routines by name, and the parameters which they plot.

## F. DATA ANALYSIS

Performance test data were routinely processed using the modified reduction programs given in Appendix A.

Data from RPM sampling tests were plotted using software given in Appendix A. Also, too, RPM data sets, at different RPM's, were analyzed by Fourier analysis, using a Hewlett-Packard 9845A waveform analysis program. Each set of data was first transformed by removing the "DC" component, i.e., averaging 256 data points and then subtracting the average from each data point. The data were then fed, separately, into the program and, after transforming to the frequency domain, a power spectrum was plotted. The power spectrum used in the program employs Raleigh's Theorem of Conjugate Multiplication (see Ref. 10), to obtain the plot. After obtaining the power spectrum plots, the magnitudes of the first forty points were taken from each of the plots,

multiplied together, and used to produce a third plot. The third plot was designed to determine whether a natural frequency (and harmonics) were present at different speeds.

A comparison of calculated and measured temperature drops was made using data from runs 10-15. The procedure consisted of taking the horsepower of the stage calculated from speed and torque measurements and computing the temperature drop across the stage which would be required to produce that horsepower. The computed "delta T" was then compared to the measured "delta T" across the stage at the different stagnation pressures and temperatures of the tests.

An investigation was conducted on runs 12 and 13 to determine what effects were evident on the reduced data of inserting a constant value of $\dot{W}_{ref}$ = 1.02 lbm/sec. This was done by inserting a line 590 in program TTR2 setting $\dot{W}_{ref} = 1.02$, re-reducing the raw data from these runs and then batch processing the results.

# III. RESULTS

## A. PRESENTATION OF RAW AND REDUCED DATA

The results of the Fourier Analysis applied to RPM samples taken at 15000 RPM and 19000 RPM are given in Tables III through XII. The tables contain the raw data, data transformed by removing the "DC" component, time domain presentation, frequency domain presentation, and finally, the power spectrum data for each RPM. The correlation of the first 40 points of the power spectrum for the two RPM's is presented in Tables XIII and XIV. The raw correlation is contained in Table XIII, and the referred form in Table XIV. The referred form was obtained by dividing each value in Table XIII by the largest value (point 5).

Table XV is a listing of the symbols used in Tables XVI through XXXVII. Figure 7 shows the pressure tap locations referred to in Tables XVII through XXX. The calculated and measured temperature drops from runs 10-15 are presented in Table XVI. The raw data for runs 10-15 are presented as voltages in Tables XVII through XXII. The performance data, engineering data, and converted raw data for selected parameters in runs 10-15 are presented in Tables XXIII through XXVIII. The results obtained by setting $W_{ref}$ = 1.02 = constant are presented in Tables XXIX and XXX for runs 12 and 13. The results of tests to evaluate numbers of samples of key parameters to be averaged are presented in Table XXXI.

## B. PRESENTATION OF GRAPHS

The graphs of RPM samples taken at speeds ranging from 10600 to 20000 RPM are presented in Figures 8 through 20. The sampling rate is shown on each figure. Graphs of the power spectrum for 15000 and 19000 RPM are presented in Figures 21 and 22. The correlation of these two spectrums for the first 40 points of the frequency domain is presented in Figure 23.

The graphs of four selected stage performance parameters using the data given in Tables XXIII through XXVIII are presented in Figures 24 through 27. The effects of total temperature and total pressure variations on $P_1/P_{t_o}$, stator nozzle taps, stator loss coefficient, and selected raw data parameters are presented in Figures 28-36. Analog records of the time variation in selected data channels are shown in Figs. 37-40.

Finally, the various aspects of repeatability are graphically depicted in Figures 41 through 46 for runs 12 and 13 (both conducted at the same $T_{t_o}$, $P_{t_o}$, and pressure ratio).

## C. UNCERTAINTY ANALYSIS

An uncertainty analysis was conducted for run 10, point 1 to evaluate the uncertainty in stator and rotor loss coefficients resulting from specified uncertainties in the measurements. The detailed analysis is presented in Appendix C. An outgrowth of the analysis was the discovery of the predominant dependence of both loss coefficients on the accuracy of the calculated value of the resultant axial force. As a

result, a simplification was found which allowed the calculation of the uncertainty in the resultant axial force, $P_1/P_{t_o}$ pressure ratio, and stator and rotor loss coefficients to be incorporated easily into a computer program, and made a part of the current reduction program sequence. Sample calculations showed only a slight deviation from exact results using this simplification (see Appendix C). The integration of this new program, called "UNCERT", into the reduction sequence is discussed in detail in Appendix A and Appendix C. It should be noted that the simplification used in the program underestimates the percentage error in stator loss coefficient by .03 times the actual error. In rotor loss coefficient the underestimate is .10 times the actual error. A complete exercise of this new program for runs 10-15 is presented in Tables XXXII to XXXVII. The uncertainties assigned to the raw data parameters presented in Appendix A were the same as those in Ref. 1. They were also consistent with the deviations found in samples conducted during the present investigation.

Of note in the results of the calculations was discovery of a nearly constant uncertainty interval for each loss coefficient. For the stator loss coefficient the uncertainty interval was approximately ±.03 and for rotor loss coefficient, approximately ±.05 to ±.08.

It was also discovered that the pressures on ports 11 and 21 contributed collectively, fully 65% of the uncertainty interval in the resultant axial force. These channels

correspond to hood pressure and static pressure at stator tap "HUB #3" (or clearance-plate cavity pressure) respectively. An increase in accuracy and stability in these two measurements would improve significantly the uncertainty interval in both loss coefficients. It should be noted that the analysis in Appendix C takes account only of "normal" sampling uncertainty in the measurements and does not consider errors introduced through calibration, instabilities, or repeatability problems.

Finally, anomalies occurred in the raw data on runs 13 and 15 which required altering the reduction sequence. The anomalies with modifications to the reduction program are listed in Table A-XX.

# IV. DISCUSSION

## A. RPM INSTABILITY

The RPM stability was examined in early tests by digitizing repetitive samples using the HP Universal counter on-line to the HP 9830A and plotting the results. This capability, which had not existed previously, quickly showed that the RPM variations were unacceptable at all RPM's. Figure 8 illustrates the problem at a low sampling rate of 27 samples per minute. RPM deviations of greater than +/- 500 RPM were common. It was also found that changing the counter control setting in the data acquisition program could drastically alter the appearance of the output. The longer was the sampling interval, the more stable appeared the RPM in the plotted output. Figures 8 through 11 illustrate this effect. The data in the four figures were taken at the same RPM and only the counter setting was changed in the acquisition program. The graphs are labelled according to sample interval. There seems to be a relationship between the sample rate and the magnitude of the recorded variations. At a sample rate of 100 samples/min., the variation was ± 200 RPM. At a sample rate of 6 samples/min., the variation was ± .2 RPM. The most useful rate seemed to be 330 samples/min., which gave relatively good repeatibility (± 20 RPM), and gave a plot which qualitatively agreed well with independent observations of RPM variations during the tests.

Figure 8 shows results with no "slingers" installed on the waterbrake. Figures 9 through 12 were samples taken with one "slinger" installed. The RPM control was still unacceptable in that RPM variations were far in excess of those required to obtain repeatable performance data. The addition of a second "slinger" produced a marked change in stability. Figures 13 through 17 show the magnitude of the RPM excursions from the set point with two "slingers" installed. A comparison with Figures 10 and 12 illustrates the improvement obtained. The addition of the slingers clearly provided a substantial improvement in stability in the speed range up to 16500 - 17000 RPM. Between 17000 and 18500 RPM, a range of severe instability still existed, as seen in Figure 17. The RPM instability seems to decrease at 19000 to 20000 RPM as shown by Figures 18 and 19, with 20000 RPM being more stable, consistently, than 19000 RPM.

These observations suggested that there might be a natural resonance encountered between 17000 and 19000 RPM. To evaluate this possibility a Fourier analysis was carried out on two sets of data taken at RPM's of 15000 and 19000, on each side of the instability. The power spectra calculated for the two sets of data are shown in Figures 21 and 22. There were seen to be peaks in the low frequency end of the scale as was suspected from an examination of the RPM vs. time plots. The correlation of the two power spectra was calculated and is shown in Figure 23. A

definite peak at .107 Hz (period about 9.3 sec.) is evident with a second harmonic exactly at .214 Hz. It can be concluded that an unsteadiness at a frequency of .107 Hz exists which does not depend on the rotational speed. Furthermore, the low frequency of the instability suggests the problem lies within the controller or the waterbrake mechanics. Satisfactory speed stability is obtained up to and beyond the 17000 to 18500 RPM range. For the moment, it is recommended that this range be avoided when taking data. It is also recommended that further testing be undertaken to attempt to improve the speed stability in this range by small modifications of the waterbrake geometry.

## B. TOTAL TEMPERATURE AND TOTAL PRESSURE EFFECTS

Runs 10 and 11 were conducted at different total pressures (59.7 and 74.5 in Hg, respectively), but at nearly equal values of the total temperature (635-639°R) and stage pressure ratio, (3.5). As can be seen in Figures 24 through 27, the various stage performance parameters, such as referred horsepower, efficiency, referred rotor torque, and referred flow rate, were measurably unaffected by total pressure changes. Also, referring to Figures 28 through 30, the stator nozzle taps and the stator exit pressure ratios are also unaffected by total pressure changes. It was concluded, therefore, that the total pressure had no measurable effect on the

interstage or stage performance parameters as long as stage pressure ratio remained constant.

Runs 10 and Runs 12 through 15 were conducted at different total temperatures (574-676°R), but at nearly equal values of the total pressure ( 60  inches Hg) and the same pressure ratio (3.5). Figures 24 through 27 and 31 again show that there was no perceptible difference in overall stage performance. However, the interstage performance varies markedly. Figures 28 and 29 show that there was a difference in stator nozzle tap pressure ratios at taps 3 and 4 in the supersonic portion of the nozzle. The locations of the taps are shown in Figure 7. Pressure tap 1 was not connected in these tests. Tap 2 is located at the throat of the nozzle, and taps 3 through 5 are located in the supersonic portion of the nozzle. The stator exit pressure ratios, $P_{HUB}/P_{t_o}$, $P_1/P_{t_o}$, $P_{TIP}/P_{t_o}$, were also examined. Figure 30 shows that there was a definite change in each of the three pressure ratios with temperature. The results for two different stage pressure ratios, 3.5 and 4.0, respectively, are shown together with data from Ref. 1 in Figures 32 and 33. Runs 8 and 9 ($T_{t_o}$ =638°R) in the present test series differed from Runs 10 and 11 in Ref. 1 ($T_{t_o}$ =670°R), in total temperature only. The same temperature effect was evident at both pressure ratios. Finally, Figures 34 through 36 show the effect of temperature on the referred stator torque, resultant axial force, and stator loss coefficient, respectively. Again, the effect was clearly measurable.

In attempting to explain the variations in interstage parameters with total temperature, it should be noted that changes in stagnation pressure and temperature should produce no changes in any referred quantities (such as referred stator torque) at given values of pressure ratio and referred speed, unless geometry changes occur or the Reynolds number is particularly low. Also, at a constant total pressure, total temperature should have no effect on pressure ratios in the flow of a perfect gas through a De Laval nozzle. The observed pressure ratio differences in particular in the values of $P_1/P_{t_o}$, evident in Figures 29, 31, and 32, in turn affect the calculation of other interstage parameters such as the resultant axial force (RAF) and the stator loss coefficient. In fact the differences evident in these derived parameters with total temperature are directly related to the shifts in $P_1/P_{t_o}$ with total temperature. Several avenues were investigated to explain the temperature effect. A summary follows:

(1) Effect of Reynolds Number

Differences in the nozzle boundary layer development resulting from the effect of stagnation temperature on the Reynolds number were considered. However, the Reynolds number variation obtained by changing stagnation pressure level more than overlapped the variation obtained by changing stagnation temperature. Since the results were unaffected by stagnation pressure changes, this could not be the mechanism.

### (2) Non-Perfect Gas Effects

The effect of temperature on the gas constant, ratio of specific heats and compressibility factor for air in the range of temperature of the tests, was found to have an insignificant effect on the predicted nozzle ratios.

### (3) Thermal Expansion Effects

Geometry changes as a result of thermal effects could occur and affect the measurements in a variety of ways. It is important to note first that uniform expansion of the stator nozzles, so that A/A* remained constant, would leave the stator pressure ratio's unaffected.

The observed decrease in static pressure ratio (or increase in Mach number) at increased stagnation temperature, would imply that the throat area was required to expand proportionately less than than the downstream section of the nozzle. Calculations were carried out assuming no change in the throat size and linear growth of the aluminum nozzle material to the higher temperature. The change in area ratio was calculated to be less than 0.003. At tap 4 in the stator nozzles, the pressure ratio increased from 0.281 in Run 11 to 0.310 in Run 12. This corresponded to an area ratio decrease from 1.162 to 1.120 (using isentropic gas tables), or an area ratio change of 0.042. This was an order of magnitude greater than could be explained by simple thermal expansion.

The fractional change in the throat area of the stator nozzles due to thermal expansion between the lowest and highest stagnation temperatures, would also be less than 0.003. An examination of the values of the referred flow rate, which is a measure of the throat area if the flow is choked, revealed that for all tests except Run 12 they ranged within ±0.005 of the value 1.025. This was consistent with the uncertainty calculated in Appendix C, resulting from the basic uncertainty in the individual measurements. In order to examine the effect of the small variations in $\dot{W}_{ref}$ on the calculated parameters, the data of Run 12 and Run 13 were re-reduced using $\dot{W}_{ref} = 1.02$ in place of the measured flow rate (see Tables XXIX and XXX). A negligible effect on the values of interstage pressure ratio was observed.

The effect of temperature on the labyrinth leak rate was questioned. In the existing reduction programs the effect of temperature on the "kinetic energy" factor had been included in the original calibration of Robbins [Ref. 8]. No correction was included however for the effect of temperature on the labyrinth clearance. When this was added (Appendix A), the effect on the results was found to be negligible.

It was concluded that thermal expansion could not explain the observed effect of temperature on nozzle pressure ratios.

(4) Condensation

It was questioned whether condensation could be occurring in flow in the supersonic portion of the nozzle. Condensation would certainly alter the static pressure levels, and condensation of the same air had been observed in the flow from a Mach 1.4 nozzle exhausting into the laboratory. A calculation was done to determine static temperatures in the flow assuming an isentropic expansion of air and water vapor through the stator nozzle. The calculation is presented in detail in Appendix D. The calculation predicted supercooled conditions for the water vapor in the entire supersonic portion of the nozzle. Supercooling in excess of 100° F was predicted at a stagnation temperature ($T_{t_o}$) of 574° R. A higher $T_{t_o}$ (670° R) resulted in supercooling of only 37° F at the nozzle exit plane. Refs. 14 and 15 state that supersonic flow containing water vapor, supercooled by 90-110° F will result in condensation. The data for low $T_{t_o}$ fall precisely in this range, so that condensation might well have occurred. Inspection of columns P2 through P4 in Tables XXIII to XXVIII reveals that as total temperature was raised, the values in these columns progressed non-linearly toward the values for the highest total temperature, (Run 15 - $T_{t_o}$ = 676° R).

A test was conducted at a total temperature of 575° R and pressure ratio of 3.5 with the rotor removed, and hood exhausted to see if condensation could be observed

(visually) in the flow exiting the stator nozzle. No condensation was observed, but it should be noted that following the calculation in Appendix D, only 4.6% of the small amount of water in the flow must condense to effect observed changes in the stator nozzle pressure ratio at M = 1.2. The small scale of the nozzles, the swirling flow geometry and the background of metallic surfaces, did not help the detection process.

A comparison of the temperature drops through the stage calculated from the torque-measurement of power, with the value measured using thermocouple probes is shown in Table XVI. It can be seen that the difference between the two measures is large at the low supply temperature, and small for the high temperature runs. Since the measurements of the referred power were in good agreement for all tests, the difference must be the result of an error in the outlet thermocouple indication, or in the assumption of perfect gas made in the calculation. Both effects would accompany the occurrence of condensation. It was therefore concluded that the changes experienced in nozzle pressure ratios and stator exit pressure ratios were directly related to condensation effects in the nozzle. It is noted however that operation at the highest temperature gave consistent results, so that condensation effects were absent, or minor.

While testing at high total temperatures in Run 15 ($T_{t_o}$ = 676° R), several pressure ports "blew" due to

the plastic pressure tubing currently used; the plastic tubing softened, and failed at the elevated temperature. In order to obtain consistent, reliable results from the rig measurements, it is essential that high total temperatures be used to suppress condensation. It is therefore recommended that 1) the rig be reinstrumented using high temperature plastic tubing. (Plastic tubing is currently available commercially for use at temperatures up to 250° F (710° R).) It is also recommended that 2) a minimum run total temperature no lower than 680° R, and preferably higher, be adopted for all performance testing in which interstage measurements are needed. To ensure that the highest total temperature is attained consistently, it is recommended that the aftercooler be drained when conducting such tests.

## C. CALCULATION OF THE REFERRED FLOW RATE AND LOSS COEFFICIENTS

Sequential scanning of the fourteen nonpressure channels revealed that for a given RPM, temperature and pressure variations were extremely small for normal RPM variations (±175 RPM). For this reason, the temperatures and all pressures except one were eliminated from the scan averaging techniques employed in Ref. 1 (see also Appendix A). It was found that channel 24, the stator exit tip static pressure, was observed visually on the mercury manometer board to oscillate ± 0.50 in Hg during tests. Channel 24 was therefore averaged when taking data (see Appendix A for full details). In addition, the

two force and two torque measurements were examined to determine how many samples per run point were required to produce a repeatable average value of the measurement. Table XXXI shows the results of this experiment. It can be seen that approximately 30 averaged samples produced a repeatable average in these parameters. On the basis of these results a 30 scan sequence was included in the acquisition program. It is also of note that the variations in stator torque and resultant axial force after 30 scans are consistent with the uncertainty intervals assigned in Ref. 1 and in this report.

Time traces of the analog output of axial force, closure force, stator torque, and rotor torque in comparison with an analog recording of the RPM are presented in Figures 37 to 40. The traces were taken at 16000 RPM. The variations in both force measurements were seen to correlate well with RPM variations and this implies that improvements in RPM stability will also result in reduced uncertainty in the computation of resultant axial force. It should be remembered however, that, as shown in Appendix D, the two pressure port measurements (11 and 21) overwhelmingly dominate in producing the uncertainty in the resultant axial force. The variation of stator torque with RPM was small and this was consistent with the 100 sample survey in Table XXXI. Finally, the variations in the rotor torque were larger than in the stator torque which again was consistent with the results of Table XXXI. However, the rotor torque variations were seen to correlate poorly with RPM variations and exhibited the most noise and scatter.

Three key parameters, $\dot{W}_{ref}$, $\zeta_S$, and $\zeta_R$, are calculated in the course of the data reduction, and the accuracy obtained depends on many measurements. What follows is a discussion of the various factors affecting the calculation of these three parameters:

A comparison of Runs 12 and 13 revealed that there were differences in both $\dot{W}_{ref}$ and $\zeta_S$ which could not be readily explained by the differences in total temperature, total pressure, or by the possible occurrence of condensation. Both runs were conducted at identical temperatures (574° R), pressures (60 in Hg), pressure ratios (3.5), and relative humidities (70%). Inspection of Tables XXV and XXVI revealed approximately a 1/2 % change in $\dot{W}_{ref}$. In addition, Figure 41 showed clearly that there were differences in $\zeta_S$. Calculations of $\dot{W}_{ref}$ involve three measurements; the pressure and the temperature upstream of and the pressure difference across the flow nozzle, which is located in the line from the Allis-Chalmers compressor to the rig inlet plenum. By interrogating the reduction programs it was revealed that the effects of small (realistic) changes in nozzle pressure or temperature affected the values of $\dot{W}_{ref}$ very slightly. However, the value of $\dot{W}_{ref}$ was affected significantly by small (but realistic) changes in the pressure drop across the flow nozzle. Point 3 on Run 12 and point 5 on Run 13 were compared. It was found that the $\Delta P$ across the nozzle was 20.884 in $H_2O$ for the first point and 21.079 for the second point. This is a change of .195 in $H_2O$ representing a .9% change in

value; but this difference is sufficient to explain most of the difference in the $\dot{W}_{ref}$. Inspection of all values of $\dot{W}_{ref}$ for Runs 10-15 revealed only ± .002 lbm/sec variation in the magnitude in any given run. However, the average $\dot{W}_{ref}$ changed slightly from run to run. Based on the comparison of Runs 12 and 13, this would appear to be due to slight drifts in transducer output during different tests, or to minor calibration errors either before or during the runs. It is therefore recommended that the calibration of the $\Delta P$ nozzle transducer be checked rigorously by the investigator at intervals throughout each test.

A re-reduction of data from Runs 12 and 13 was carried out with $\dot{W}_{ref} = 1.02$ lbm/sec = constant entered into the program as discussed in Section IV.B. This re-reduced data is presented in Tables XXIX and XXX. The original stator loss coefficient data are shown in Figure 41 and the re-reduced data are shown in Figure 42. It can be seen that, while the calculated stator loss coefficients were in better agreement than before, they were still higher in Run 13. The effects of $\dot{W}_{ref}$ then do not account totally for the differences seen in $\zeta_S$ (and $\zeta_R$). The data in Figure 43 illustrates that, although there were differences in $\zeta_S$ and $\zeta_R$ that again, stage performance parameters were nearly the same. Figures 44, 45 and 46, containing data from Run 12 and Run 13 show that there was only a slight difference in measured stator torque between the two runs, but a definite correlation exists in the behavior of the calculated resultant axial force (RAF)

and the calculated interstage pressure ratio ($P_1/P_{t_o}$). The distribution of the data in Figures 45 and 46 is entirely similar. This result is in complete agreement with the results of the uncertainty analysis given in Appendix D which emphasizes the dominance of RAF on the calculation of $P_1/P_{t_o}$. This also points to the necessity for an extremely careful calibration of the force capsules before each run.

The stator hub and tip pressures, on ports 21 and 24, were observed (on the mercury manometer board) to exhibit unsteady behavior. The unsteadiness on Port 24 was qualitatively worse than on port 21 by about a factor of two. The acquisition program was altered initially to average both these ports over 30 scans. However, this resulted in the Scanivalve having to cycle completely through 48 channels for each of the 30 samples. This procedure required 300 cycles of the Scanivalve to obtain ten data points in each performance test. Excessive scanivalve wear would result from such a procedure. It was therefore decided to only average port 24 since it was observed to be the most unsteady. However, the uncertainty analysis revealed that port 21 exercises a far greater influence on the uncertainty in the resultant axial force than does port 24, by a factor of nearly 26. In selecting between the two measurements, port 21 should have been averaged, not port 24. It is therefore recommended that a pneumatic damper be inserted in the pressure lines to each of ports 21 and 24. An improvement in the steadiness of the pressure at these two ports, particularly 21, should result

in a significant improvement in the steadiness and reliability of the calculated values of resultant axial force, interstage pressure ratio, stator and rotor loss coefficients. The proper averaging of the pressures on these two ports would do more to improve the reliability and smoothness of the output calculations than any other recommendation which has been made. Hood pressure, the other key input affecting the resultant axial force calculation, was observed to be very steady throughout all tests.

In summary, it is recommended that, prior to each run, the investigator, with the cooperation of the test engineer, carry out a systematic verification of the calibration of the measurements shown to have a controlling effect on the reduced data. Where practical, calibrations should be verified at intervals throughout the test period. The key parameters and recommended procedures to follow are given in Appendix E.

# V. CONCLUSIONS

1. The speed control of the waterbrake and turbine system manifests a characteristic frequency of .107 Hz at speeds of both 15,000 and 19,000 RPM.

2. There is a region of instability in the RPM control between 17000 - 18500 RPM which is caused by either instability in the flow of water through the waterbrake or by the inability of the controller to control the turbine output characteristic in this range.

3. Operation of the rig is satisfactory outside the range of the instability.

4. Variations in $P_{t_o}$, with stage pressure ratio held constant, have no measurable influence on the interstage or stage performance parameters.

5. Variations in $T_{t_o}$, with stage pressure ratio held constant had no measurable effect on stage performance. Changes experienced in stator nozzle pressure ratio and stator exit pressure ratios (and consequently, loss coefficients) were directly related to condensation effects beginning in the stator nozzle.

6. Approximately 30 scans of stator and rotor torque and axial and closure force measurements were required to produce a repeatable average for a given data point.

7. The pressure drop across the flow nozzle, $\Delta P_{noz}$, has the greatest influence of the three input measurements on the calculated value of $W_{ref}$.

8. To ensure accurate computation of RAF, a careful, accurate calibration of the force measurements must be conducted before each run.

9. Pressure ports 11 (hood pressure) and 21 (stator exit hub pressure) exert a disproportionate influence on the uncertainty in calculating the resultant axial force (RAF), stator exit pressure, and stator and rotor loss coefficients. An increase in accuracy in measuring these two pressures would result in a significant decrease in the variations found in each of the above-mentioned calculated parameters.

10. The stator exit hub pressure on Port 21, is unsteady and exerts a stronger influence on the uncertainty in RAF than does the tip pressure on port 24.

11. A pneumatic damper on ports 21 and 24 would do more to improve the accuracy of the calculated values of the resultant axial force, interstage pressure, stator and rotor loss coefficients than any other change which could be made.

12. A nearly constant uncertainty interval exists in $\zeta_S$ of $\pm.0300$ and in $\zeta_R$ of $\pm.05$ to .08.

# VI. RECOMMENDATIONS

1. The speed range of 17000 - 18500 RPM be avoided until the waterbrake instability in this area is corrected.

2. Further tests be conducted to attempt to improve the waterbrake stability by perturbing the internal geometry.

3. The pressure tubing inside the hood be replaced with high temperature plastic tubing to allow the use of temperatures up to 710 °R.

4. A minimum total temperature of 680° R or higher be adopted to avoid condensation effects when interstage data is taken. This can be done by draining the aftercooler.

5. A pneumatic damper be incorporated in the port 21 and port 24 pressure lines to improve accuracy in calculating interstage parameters. An improvement in speed stability will alleviate, but not eliminate this requirement.

6. The investigator should check the calibration of the $\Delta P_{noz}$ transducer before and after each data point to ensure accuracy in $\dot{W}_{ref}$.

7. The investigator should cooperate with the test engineer to verify the calibration of key measurements by following, at a minimum, the steps listed in Appendix E.

8. Merging the acquisition and reduction programs should be considered and implemented if found to be practicable.

# TABLE I

## TESTS CONDUCTED

### TURBINE PERFORMANCE TESTS

| Run Number | $T_{t_o}$ (°R) | $P_{t_o}$ ("Hg) | Pressure Ratio | RPM |
|---|---|---|---|---|
| 8 | 639 | 59.8 | 3.5 | 10040-18870 |
| 9 | 643 | 59.6 | 4.0 | 11000-18750 |
| 10 | 635 | 59.7 | 3.5 | 11077-19346 |
| 11 | 639 | 74.5 | 3.5 | 11129-18017 |
| 12 | 574 | 59.8 | 3.5 | 12214-19046 |
| 13 | 574 | 59.9 | 3.5 | 12085-20009 |
| 14 | 602 | 60.0 | 3.5 | 12075-19987 |
| 15 | 676 | 59.9 | 3.6 | 12081-19940 |

### RPM SAMPLE TESTS

| Run Number | Pressure Ratio | RPM |
|---|---|---|
| 1 | 3.0 | 10600 |
| 2 | 3.0 | 11600 |
| 3 | 3.0 | 11600 |
| 4 | 3.0 | 11600 |
| 5 | 3.0 | 11600 |
| 6 | 3.0 | 13000 |
| 7 | 3.0 | 14100 |
| 8 | 3.0 | 15100 |

| | | |
|---|---|---|
| 9 | 3.0 | 16100 |
| 10 | 3.5 | 17400 |
| 11 | 3.0 | 19000 |
| 12 | 3.5 | 20000 |

*RPM samples were taken on most occasions between performance test points. No attempt has been made to equate these run numbers with those listed as turbine performance tests. RPM sample tests are sequentially numbered and correspond to the order of graphs of results presented in the report.

## DATA SAMPLE TEST

One test was run to determine the number of samples needed to produce a constant average in the forces (two measurements), and torques (two measurements). The test was run at 11500 RPM, pressure ratio of 3.0, and 100 samples were taken of each parameter of interest.

## TABLE II

## STORAGE LOCATION OF RAW AND REDUCED DATA

### TURBINE PERFORMANCE TESTS

| Run Number | Record Number | File Name |
|---|---|---|
| 1 | 1-10 | |
| 2 | 11-20 | |
| 3 | erased | |
| 4 | 21-30 | Raw Data in file "RAWDAT" |
| 5 | 31-40 | |
| 6 | 41-50 | |
| 7 | 51-59 | Reduced Data in file "REDDAT" |
| 8 | erased | |
| 9 | erased | |
| 10 | 60-68 | |
| 11 | 69-76 | |
| 12 | 77-82 | |
| 13 | 83-90 | |
| 14 | 91-98 | |
| 15 | 99-106 | |

### RPM SAMPLE TESTS

| # Slingers | RPM | Record Number | File Name |
|---|---|---|---|
| 1 | 11500 | 1-3 | |
| 1 | 11500 | 4-6 | |
| 1 | 11500 | 7-9 | |
| 1 | 11500 | 10-12 | Data stored in file "RPMSTO" |
| 1 | 11500 | 13-15 | |
| 2 | 11500 | 16-18 | |
| 2 | 11500 | 19-21 | |
| 2 | 10400 | 22-24 | |
| 2 | 13100 | 25-27 | |
| 2 | 19000 | 28-30 | |
| 2 | 13100 | 31-33 | |
| 2 | 14100 | 34-36 | |
| 2 | 15100 | 37-39 | |
| 2 | 19000 | 40-42 | |
| 2 | 17100 | 43-45 erased | |
| 2 | 19000 | 43-45 | |
| 2 | 20000 | 46-48 | |
| 2 | 19000 | 49-51 | |

### UNCERTAINTY MEASUREMENTS

| Run Number | Record Number | File Name |
|---|---|---|
| 10 | 1-9 | |
| 11 | 10-17 | |
| 12 | 18-23 | Stored in "DATAZ", for performance test data. |
| 13 | 24-31 | |
| 14 | 32-39 | |
| 15 | 40-47 | |

# TABLE III. RPM SAMPLES AT 15,000 RPM

| # | X | Y | # | | Y |
|---|---|---|---|---|---|
| 1 | 14980 | 0 | 2 | [illegible] | 0 |
| 3 | 15100 | 0 | 4 | 15080 | 0 |
| 5 | 15060 | 0 | 6 | 15040 | 0 |
| 7 | 15040 | 0 | 8 | 15060 | 0 |
| 9 | 15080 | 0 | 10 | 15060 | 0 |
| 11 | 15040 | 0 | 12 | 15040 | 0 |
| 13 | 15020 | 0 | 14 | 15080 | 0 |
| 15 | 15100 | 0 | 16 | 15080 | 0 |
| 17 | 15080 | 0 | 18 | 15100 | 0 |
| 19 | 15120 | 0 | 20 | 15120 | 0 |
| 21 | 15200 | 0 | 22 | 15180 | 0 |
| 23 | 15120 | 0 | 24 | 15100 | 0 |
| 25 | 15100 | 0 | 26 | 15140 | 0 |
| 27 | 15140 | 0 | 28 | 15120 | 0 |
| 29 | 15100 | 0 | 30 | 15140 | 0 |
| 31 | 15160 | 0 | 32 | 15240 | 0 |
| 33 | 15240 | 0 | 34 | 15240 | 0 |
| 35 | 15260 | 0 | 36 | 15240 | 0 |
| 37 | 15200 | 0 | 38 | 15160 | 0 |
| 39 | 15140 | 0 | 40 | 15140 | 0 |
| 41 | 15140 | 0 | 42 | 15080 | 0 |
| 43 | 15040 | 0 | 44 | 15020 | 0 |
| 45 | 14960 | 0 | 46 | 14960 | 0 |
| 47 | 15000 | 0 | 48 | 15040 | 0 |
| 49 | 15100 | 0 | 50 | 15140 | 0 |
| 51 | 15100 | 0 | 52 | 15120 | 0 |
| 53 | 15100 | 0 | 54 | 15080 | 0 |
| 55 | 15060 | 0 | 56 | 15060 | 0 |
| 57 | 15080 | 0 | 58 | 15100 | 0 |
| 59 | 15100 | 0 | 60 | 15080 | 0 |
| 61 | 15080 | 0 | 62 | 15080 | 0 |
| 63 | 15040 | 0 | 64 | 15060 | 0 |
| 65 | 15100 | 0 | 66 | 15100 | 0 |
| 67 | 15120 | 0 | 68 | 15200 | 0 |
| 69 | 15160 | 0 | 70 | 15180 | 0 |
| 71 | 15180 | 0 | 72 | 15140 | 0 |
| 73 | 15120 | 0 | 74 | 15120 | 0 |
| 75 | 15120 | 0 | 76 | 15140 | 0 |
| 77 | 15140 | 0 | 78 | 15160 | 0 |
| 79 | 15180 | 0 | 80 | 15160 | 0 |
| 81 | 15160 | 0 | 82 | 15100 | 0 |
| 83 | 15100 | 0 | 84 | 15120 | 0 |
| 85 | 15120 | 0 | 86 | 15080 | 0 |
| | 15060 | 0 | 88 | 15060 | [illegible] |
| | 15060 | 0 | 90 | 15060 | [illegible] |

## TABLE III (Cont'd)

| | | | | | |
|---|---|---|---|---|---|
| | [illegible] | 0 | 92 | 15 | |
| 93 | [illegible] | 0 | 94 | 15060 | 0 |
| 95 | 15040 | 0 | 96 | 15040 | 0 |
| 97 | 15040 | 0 | 98 | 15040 | 0 |
| 99 | 15080 | 0 | 100 | 15120 | 0 |
| 101 | 15100 | 0 | 102 | 15120 | 0 |
| 103 | 15060 | 0 | 104 | 15080 | 0 |
| 105 | 15100 | 0 | 106 | 15100 | 0 |
| | 5120 | 0 | 108 | [illegible] | [illegible] |
| | 5140 | 0 | 110 | [illegible] | [illegible] |
| [illegible] | 5100 | 0 | 112 | [illegible] | [illegible] |
| 113 | 15120 | 0 | 114 | 15140 | 0 |
| 115 | 15120 | 0 | 116 | 15100 | 0 |
| 117 | 15080 | 0 | 118 | 15080 | 0 |
| 119 | 15060 | 0 | 120 | 15060 | 0 |
| 121 | 15060 | 0 | 122 | 15080 | 0 |
| 123 | 15100 | 0 | 124 | 15100 | 0 |
| 125 | 15060 | 0 | 126 | 15100 | 0 |
| 127 | 15120 | 0 | 128 | 15120 | 0 |
| 129 | 15140 | 0 | 130 | 15100 | 0 |
| 131 | 15140 | 0 | 132 | 15120 | 0 |
| 133 | 15160 | 0 | 134 | 15140 | 0 |
| 135 | 15160 | 0 | 136 | 15140 | 0 |
| 137 | 15120 | 0 | 138 | 15140 | 0 |
| 139 | 15120 | 0 | 140 | 15100 | 0 |
| 141 | 15100 | 0 | 142 | 15120 | 0 |
| 143 | 15120 | 0 | 144 | 15100 | 0 |
| 145 | 15140 | 0 | 146 | 15180 | 0 |
| 147 | 15140 | 0 | 148 | 15140 | 0 |
| 149 | 15140 | 0 | 150 | 15140 | 0 |
| 151 | 15120 | 0 | 152 | 15080 | 0 |
| 153 | 15080 | 0 | 154 | 15060 | 0 |
| 155 | 15080 | 0 | 156 | 15100 | 0 |
| 157 | 15120 | 0 | 158 | 15120 | 0 |
| 159 | 15160 | 0 | 160 | 15200 | 0 |
| 161 | 15220 | 0 | 162 | 15260 | 0 |
| 163 | 15220 | 0 | 164 | 15180 | 0 |
| 165 | 15140 | 0 | 166 | 15160 | 0 |
| 167 | 15120 | 0 | 168 | 15120 | 0 |
| 169 | 15180 | 0 | 170 | 15180 | 0 |
| 171 | 15200 | 0 | 172 | 15180 | 0 |
| 173 | 15100 | 0 | 174 | 15060 | 0 |
| 175 | 15060 | 0 | 176 | 15080 | 0 |
| [illegible] | 15120 | 0 | 178 | 15100 | 0 |
| [illegible] | 15080 | 0 | 180 | 15080 | [illegible] |

# TABLE III (Cont'd)

| | | | | | |
|---|---|---|---|---|---|
| 183 | [illegible] | | | | |
| 185 | | 0 | [illegible] | [illegible] | 0 |
| 187 | | 0 | 188 | 15140 | 0 |
| 189 | 15140 | 0 | 190 | 15140 | 0 |
| 191 | 15180 | 0 | 192 | 15160 | 0 |
| 193 | 15140 | 0 | 194 | 15140 | 0 |
| 195 | 15100 | 0 | 196 | 15030 | 0 |
| 197 | 15080 | 0 | 198 | 15040 | 0 |
| 199 | 15030 | 0 | 200 | 15100 | 0 |
| 201 | 15140 | 0 | 202 | 15120 | 0 |
| 203 | 15080 | 0 | 204 | 15080 | 0 |
| 205 | 15100 | 0 | 206 | 15120 | 0 |
| 207 | 15100 | 0 | 208 | 15120 | 0 |
| 209 | 15140 | 0 | 210 | 15120 | 0 |
| 211 | 15100 | 0 | 212 | 15100 | 0 |
| 213 | 15140 | 0 | 214 | 15120 | 0 |
| 215 | 15120 | 0 | 216 | 15060 | 0 |
| 217 | 15040 | 0 | 218 | 15080 | 0 |
| 219 | 15100 | 0 | 220 | 15080 | 0 |
| 221 | 15100 | 0 | 222 | 15060 | 0 |
| 223 | 15040 | 0 | 224 | 15040 | 0 |
| 225 | 15040 | 0 | 226 | 15020 | 0 |
| 227 | 15040 | 0 | 228 | 15040 | 0 |
| 229 | 15040 | 0 | 230 | 15060 | 0 |
| 231 | 15140 | 0 | 232 | 15200 | 0 |
| [illegible] | 15200 | 0 | 234 | 15180 | [illegible] |
| [illegible] | 5220 | 0 | 236 | 15200 | [illegible] |
| [illegible] | 5180 | 0 | 238 | 15180 | [illegible] |
| 239 | 15160 | 0 | 240 | 15160 | 0 |
| 241 | 15160 | 0 | 242 | 15160 | 0 |
| 243 | 15160 | 0 | 244 | 15120 | 0 |
| 245 | 15120 | 0 | 246 | 15100 | 0 |
| 247 | 15080 | 0 | 248 | 15080 | 0 |
| 249 | 15100 | 0 | 250 | 15060 | 0 |
| 251 | 15080 | 0 | 252 | 15080 | 0 |
| 253 | 15060 | 0 | 254 | 15040 | 0 |
| 255 | 15060 | 0 | 256 | 15120 | 0 |

## TABLE IV

## RPM UNSTEADY COMPONENT AT 15000 RPM

AVG = 15110.46875

| | | | |
|---|---|---|---|
| -130.46875 | -90.46875 | -10.46875 | -30.46875 |
| -50.46875 | -70.46875 | -70.46875 | -50.46875 |
| -30.46875 | -50.46875 | -70.46875 | -70.46875 |
| -90.46875 | -30.46875 | -10.46875 | -30.46875 |
| -30.46875 | -10.46875 | 9.53125 | 9.53125 |
| 89.53125 | 69.53125 | 9.53125 | -10.46875 |
| -10.46875 | 29.53125 | 29.53125 | 9.53125 |
| -10.46875 | 29.53125 | 49.53125 | 129.53125 |
| 129.53125 | 129.53125 | 149.53125 | 129.53125 |
| 89.53125 | 49.53125 | 29.53125 | 29.53125 |
| 29.53125 | -30.46875 | -70.46875 | -90.46875 |
| -150.46875 | -150.46875 | -110.46875 | -70.46875 |
| -10.46875 | 29.53125 | -10.46875 | 9.53125 |
| -10.46875 | -30.46875 | -50.46875 | -50.46875 |
| -30.46875 | -10.46875 | -10.46875 | -30.46875 |
| -30.46875 | -30.46875 | -70.46875 | -50.46875 |
| -10.46875 | -10.46875 | 9.53125 | 89.53125 |
| 49.53125 | 69.53125 | 69.53125 | 29.53125 |
| 9.53125 | 9.53125 | 9.53125 | 29.53125 |
| 29.53125 | 49.53125 | 69.53125 | 49.53125 |
| 49.53125 | -10.46875 | -10.46875 | 9.53125 |
| 9.53125 | -30.46875 | -50.46875 | -50.46875 |
| -50.46875 | -50.46875 | -50.46875 | -10.46875 |
| -10.46875 | -50.46875 | -70.46875 | -70.46875 |
| -70.46875 | -70.46875 | -30.46875 | 9.53125 |
| -10.46875 | 9.53125 | -50.46875 | -30.46875 |
| -10.46875 | -10.46875 | 9.53125 | 9.53125 |
| 29.53125 | -10.46875 | -10.46875 | 9.53125 |
| 9.53125 | 29.53125 | 9.53125 | -10.46875 |
| -30.46875 | -30.46875 | -50.46875 | -50.46875 |
| -50.46875 | -30.46875 | -10.46875 | -10.46875 |
| -50.46875 | -10.46875 | 9.53125 | 9.53125 |
| 29.53125 | -10.46875 | 29.53125 | 9.53125 |
| 49.53125 | 29.53125 | 49.53125 | 29.53125 |
| 9.53125 | 29.53125 | 9.53125 | -10.46875 |
| -10.46875 | 9.53125 | 9.53125 | -10.46875 |
| 29.53125 | 69.53125 | 29.53125 | 29.53125 |
| 29.53125 | 29.53125 | 9.53125 | -30.46875 |
| -30.46875 | -50.46875 | -30.46875 | -10.46875 |
| 9.53125 | 9.53125 | 49.53125 | 89.53125 |
| 109.53125 | 149.53125 | 109.53125 | 69.53125 |
| 29.53125 | 49.53125 | 9.53125 | 9.53125 |

# TABLE IV (Cont'd)

| | | | |
|---|---|---|---|
| 69.53125 | 69.53125 | 89.53125 | 69.53125 |
| -10.46875 | -50.46875 | -50.46875 | -30.46875 |
| 9.53125 | -10.46875 | -30.46875 | -30.46875 |
| -30.46875 | 29.53125 | 49.53125 | 29.53125 |
| 49.53125 | 69.53125 | 29.53125 | 29.53125 |
| 29.53125 | 29.53125 | 69.53125 | 49.53125 |
| 29.53125 | 29.53125 | -10.46875 | -30.46875 |
| -30.46875 | -70.46875 | -30.46875 | -10.46875 |
| 29.53125 | 9.53125 | -30.46875 | -30.46875 |
| -10.46875 | 9.53125 | -10.46875 | 9.53125 |
| 29.53125 | 9.53125 | -10.46875 | -10.46875 |
| 29.53125 | 9.53125 | 9.53125 | -50.46875 |
| -70.46875 | -30.46875 | -10.46875 | -30.46875 |
| -10.46875 | -50.46875 | -70.46875 | -70.46875 |
| -70.46875 | -90.46875 | -70.46875 | -70.46875 |
| -70.46875 | -50.46875 | 29.53125 | 69.53125 |
| 89.53125 | 69.53125 | 109.53125 | 89.53125 |
| 69.53125 | 69.53125 | 49.53125 | 49.53125 |
| 49.53125 | 49.53125 | 49.53125 | 9.53125 |
| 9.53125 | -10.46875 | -30.46875 | -30.46875 |
| -10.46875 | -50.46875 | -30.46875 | -30.46875 |
| -50.46875 | -70.46875 | -50.46875 | 9.53125 |

## TABLE V

```
                         TIME DOMAIN DATA

NUMBER OF DATA POINTS =  256
TIME=0 TO  4.65455E+01[SEC]
TIME INTERVAL= 1.81818E-01[SEC]

    DATA POINT          TIME[SEC]              DATA
         1             0.00000E+00         -1.30469E+02
         2             1.81818E-01         -9.04688E+01
         3             3.63636E-01         -1.04688E+01
         4             5.45455E-01         -3.04688E+01
         5             7.27273E-01         -5.04688E+01
         6             9.09091E-01         -7.04688E+01
         7             1.09091E+00         -7.04688E+01
         8             1.27273E+00         -5.04688E+01

         9             1.45455E+00         -3.04688E+01
        10             1.63636E+00         -5.04688E+01
        11             1.81818E+00         -7.04688E+01
        12             2.00000E+00         -7.04688E+01
        13             2.18182E+00         -9.04688E+01
        14             2.36364E+00         -3.04688E+01
        15             2.54545E+00         -1.04688E+01
        16             2.72727E+00         -3.04688E+01

        17             2.90909E+00         -3.04688E+01
        18             3.09091E+00         -1.04688E+01
        19             3.27273E+00          9.53125E+00
        20             3.45455E+00          9.53125E+00
        21             3.63636E+00          8.95313E+01
        22             3.81818E+00          6.95313E+01
        23             4.00000E+00          9.53125E+00
        24             4.18182E+00         -1.04688E+01

        25             4.36364E+00         -1.04688E+01
        26             4.54545E+00          2.95313E+01
        27             4.72727E+00          2.95313E+01
        28             4.90909E+00          9.53125E+00
        29             5.09091E+00         -1.04688E+01
        30             5.27273E+00          2.95313E+01
        31             5.45455E+00          4.95313E+01
        32             5.63636E+00          1.29531E+02

        33             5.81818E+00          1.29531E+02
        34             6.00000E+00          1.29531E+02
        35             6.18182E+00          1.49531E+02
        36             6.36364E+00          1.29531E+02
        37             6.54545E+00          8.95313E+01
        38             6.72727E+00          4.95313E+01
        39             6.90909E+00          2.95313E+01
        40             7.09091E+00          2.95313E+01
```

TABLE V (Cont'd)

| | | |
|---|---|---|
| 41 | 7.27273E+00 | 2.95313E+01 |
| 42 | 7.45455E+00 | -3.04688E+01 |
| 43 | 7.63636E+00 | -7.04688E+01 |
| 44 | 7.81818E+00 | -9.04688E+01 |
| 45 | 8.00000E+00 | -1.50469E+02 |
| 46 | 8.18182E+00 | -1.50469E+02 |
| 47 | 8.36364E+00 | -1.10469E+02 |
| 48 | 8.54545E+00 | -7.04688E+01 |
| 49 | 8.72727E+00 | -1.04688E+01 |
| 50 | 8.90909E+00 | 2.95313E+01 |
| 51 | 9.09091E+00 | -1.04688E+01 |
| 52 | 9.27273E+00 | 9.53125E+00 |
| 53 | 9.45455E+00 | -1.04688E+01 |
| 54 | 9.63636E+00 | -3.04688E+01 |
| 55 | 9.81818E+00 | -5.04688E+01 |
| 56 | 1.00000E+01 | -5.04688E+01 |
| 57 | 1.01818E+01 | -3.04688E+01 |
| 58 | 1.03636E+01 | -1.04688E+01 |
| 59 | 1.05455E+01 | -1.04688E+01 |
| 60 | 1.07273E+01 | -3.04688E+01 |
| 61 | 1.09091E+01 | -3.04688E+01 |
| 62 | 1.10909E+01 | -3.04688E+01 |
| 63 | 1.12727E+01 | -7.04688E+01 |
| 64 | 1.14545E+01 | -5.04688E+01 |
| 65 | 1.16364E+01 | -1.04688E+01 |
| 66 | 1.18182E+01 | -1.04688E+01 |
| 67 | 1.20000E+01 | 9.53125E+00 |
| 68 | 1.21818E+01 | 8.95313E+01 |
| 69 | 1.23636E+01 | 4.95313E+01 |
| 70 | 1.25455E+01 | 6.95313E+01 |
| 71 | 1.27273E+01 | 6.95313E+01 |
| 72 | 1.29091E+01 | 2.95313E+01 |
| 73 | 1.30909E+01 | 9.53125E+00 |
| 74 | 1.32727E+01 | 9.53125E+00 |
| 75 | 1.34545E+01 | 9.53125E+00 |
| 76 | 1.36364E+01 | 2.95313E+01 |
| 77 | 1.38182E+01 | 2.95313E+01 |
| 78 | 1.40000E+01 | 4.95313E+01 |
| 79 | 1.41818E+01 | 6.95313E+01 |
| 80 | 1.43636E+01 | 4.95313E+01 |

## TABLE V (Cont'd)

| | | |
|---|---|---|
| [illegible] | [illegible] | [illegible] |
| 82 | 1.47273E+01 | -1.04688E+01 |
| 83 | 1.49091E+01 | -1.04688E+01 |
| 84 | 1.50909E+01 | 9.53125E+00 |
| 85 | 1.52727E+01 | 9.53125E+00 |
| 86 | 1.54545E+01 | -3.04688E+01 |
| 87 | 1.56364E+01 | -5.04688E+01 |
| 88 | 1.58182E+01 | -5.04688E+01 |
| 89 | 1.60000E+01 | -5.04688E+01 |
| 90 | 1.61818E+01 | -5.04688E+01 |
| 91 | 1.63636E+01 | -5.04688E+01 |
| 92 | 1.65455E+01 | -1.04688E+01 |
| 93 | 1.67273E+01 | -1.04688E+01 |
| 94 | 1.69091E+01 | -5.04688E+01 |
| 95 | 1.70909E+01 | -7.04688E+01 |
| 96 | 1.72727E+01 | -7.04688E+01 |
| 97 | 1.74545E+01 | -7.04688E+01 |
| 98 | 1.76364E+01 | -7.04688E+01 |
| 99 | 1.78182E+01 | -3.04688E+01 |
| 100 | 1.80000E+01 | 9.53125E+00 |
| 101 | 1.81818E+01 | -1.04688E+01 |
| 102 | 1.83636E+01 | 9.53125E+00 |
| 103 | 1.85455E+01 | -5.04688E+01 |
| 104 | 1.87273E+01 | -3.04688E+01 |
| 105 | 1.89091E+01 | -1.04688E+01 |
| 106 | 1.90909E+01 | -1.04688E+01 |
| 107 | 1.92727E+01 | 9.53125E+00 |
| 108 | 1.94545E+01 | 9.53125E+00 |
| 109 | 1.96364E+01 | 2.95313E+01 |
| 110 | 1.98182E+01 | -1.04688E+01 |
| 111 | 2.00000E+01 | -1.04688E+01 |
| 112 | 2.01818E+01 | 9.53125E+00 |
| 113 | 2.03636E+01 | 9.53125E+00 |
| 114 | 2.05455E+01 | 2.95313E+01 |
| 115 | 2.07273E+01 | 9.53125E+00 |
| 116 | 2.09091E+01 | -1.04688E+01 |
| 117 | 2.10909E+01 | -3.04688E+01 |
| 118 | 2.12727E+01 | -3.04688E+01 |
| 119 | 2.14545E+01 | -5.04688E+01 |
| 120 | 2.16364E+01 | -5.04688E+01 |

TABLE V (Cont'd)

| | | |
|---|---|---|
| 121 | 2,18182E+01 | -5.04688E+01 |
| 122 | 2.20000E+01 | -3,04688E+01 |
| 123 | 2.21818E+01 | -1.04688E+01 |
| 124 | 2.23636E+01 | -1.04638E+01 |
| 125 | 2.25455E+01 | -5.04688E+01 |
| 126 | 2.27273E+01 | -1,04688E+01 |
| 127 | 2.29091E+01 | 9.53125E+00 |
| 128 | 2.30909E+01 | 9.53125E+00 |
| 129 | 2,32727E+01 | 2,95313E+01 |
| 130 | 2.34545E+01 | -1,04688E+01 |
| 131 | 2.36364E+01 | 2.95313E+01 |
| 132 | 2.38182E+01 | 9.53125E+00 |
| 133 | 2.40000E+01 | 4,95313E+01 |
| 134 | 2.41818E+01 | 2,95313E+01 |
| 135 | 2.43636E+01 | 4.95313E+01 |
| 136 | 2.45455E+01 | 2.95313E+01 |
| 137 | 2.47273E+01 | 9.53125E+00 |
| 138 | 2.49091E+01 | 2.95313E+01 |
| 139 | 2.50909E+01 | 9.53125E+00 |
| 140 | 2,52727E+01 | -1.04688E+01 |
| 141 | 2,54545E+01 | -1.04688E+01 |
| 142 | 2,56364E+01 | 9.53125E+00 |
| 143 | 2,58182E+01 | 9,53125E+00 |
| 144 | 2.60000E+01 | -1.04688E+01 |
| 145 | 2.61818E+01 | 2.95313E+01 |
| 146 | 2,63636E+01 | 6.95313E+01 |
| 147 | 2,65455E+01 | 2,95313E+01 |
| 148 | 2.67273E+01 | 2.95313E+01 |
| 149 | 2,69091E+01 | 2.95313E+01 |
| 150 | 2.70909E+01 | 2.95313E+01 |
| 151 | 2.72727E+01 | 9.53125E+00 |
| 152 | 2.74545E+01 | -3.04688E+01 |
| 153 | 2.76364E+01 | -3.04688E+01 |
| 154 | 2,78182E+01 | -5,04688E+01 |
| 155 | 2.80000E+01 | -3.04688E+01 |
| 156 | 2.81818E+01 | -1,04688E+01 |
| 157 | 2.83636E+01 | 9,53125E+00 |
| 158 | 2.85455E+01 | 9,53125E+00 |
| 159 | 2.87273E+01 | 4,95313E+01 |
| 160 | 2,89091E+01 | 8,95313E+01 |

TABLE V (Cont'd)

| | | |
|---|---|---|
| 161 | 2.90909E+01 | 1.09531E+02 |
| 162 | 2.92727E+01 | 1.49531E+02 |
| 163 | 2.94545E+01 | 1.09531E+02 |
| 164 | 2.96364E+01 | 6.95313E+01 |
| 165 | 2.98182E+01 | 2.95313E+01 |
| 166 | 3.00000E+01 | 4.95313E+01 |
| 167 | 3.01818E+01 | 9.53125E+00 |
| 168 | 3.03636E+01 | 9.53125E+00 |
| 169 | 3.05455E+01 | 6.95313E+01 |
| 170 | 3.07273E+01 | 6.95313E+01 |
| 171 | 3.09091E+01 | 8.95313E+01 |
| 172 | 3.10909E+01 | 6.95313E+01 |
| 173 | 3.12727E+01 | -1.04688E+01 |
| 174 | 3.14545E+01 | -5.04688E+01 |
| 175 | 3.16364E+01 | -5.04688E+01 |
| 176 | 3.18182E+01 | -3.04688E+01 |
| 177 | 3.20000E+01 | 9.53125E+00 |
| 178 | 3.21818E+01 | -1.04688E+01 |
| 179 | 3.23636E+01 | -3.04688E+01 |
| 180 | 3.25455E+01 | -3.04688E+01 |
| 181 | 3.27273E+01 | -3.04688E+01 |
| 182 | 3.29091E+01 | 2.95313E+01 |
| 183 | 3.30909E+01 | 4.95313E+01 |
| 184 | 3.32727E+01 | 2.95313E+01 |
| 185 | 3.34545E+01 | 4.95313E+01 |
| 186 | 3.36364E+01 | 6.95313E+01 |
| 187 | 3.38182E+01 | 2.95313E+01 |
| 188 | 3.40000E+01 | 2.95313E+01 |
| 189 | 3.41818E+01 | 2.95313E+01 |
| 190 | 3.43636E+01 | 2.95313E+01 |
| 191 | 3.45455E+01 | 6.95313E+01 |
| 192 | 3.47273E+01 | 4.95313E+01 |
| 193 | 3.49091E+01 | 2.95313E+01 |
| 194 | 3.50909E+01 | 2.95313E+01 |
| 195 | 3.52727E+01 | -1.04688E+01 |
| 196 | 3.54545E+01 | -3.04688E+01 |
| 197 | 3.56364E+01 | -3.04688E+01 |
| 198 | 3.58182E+01 | -7.04688E+01 |
| 199 | 3.60000E+01 | -3.04688E+01 |
| 200 | 3.61818E+01 | -1.04688E+01 |

TABLE V (Cont'd)

| | | |
|---|---|---|
| 201 | 3.63636E+01 | 2.95313E+01 |
| 202 | 3.65455E+01 | 9.53125E+00 |
| 203 | 3.67273E+01 | -3.04688E+01 |
| 204 | 3.69091E+01 | -3.04688E+01 |
| 205 | 3.70909E+01 | -1.04688E+01 |
| 206 | 3.72727E+01 | 9.53125E+00 |
| 207 | 3.74545E+01 | -1.04688E+01 |
| 208 | 3.76364E+01 | 9.53125E+00 |
| 209 | 3.78182E+01 | 2.95313E+01 |
| 210 | 3.80000E+01 | 9.53125E+00 |
| 211 | 3.81818E+01 | -1.04688E+01 |
| 212 | 3.83636E+01 | -1.04688E+01 |
| 213 | 3.85455E+01 | 2.95313E+01 |
| 214 | 3.87273E+01 | 9.53125E+00 |
| 215 | 3.89091E+01 | 9.53125E+00 |
| 216 | 3.90909E+01 | -5.04688E+01 |
| 217 | 3.92727E+01 | -7.04688E+01 |
| 218 | 3.94545E+01 | -3.04688E+01 |
| 219 | 3.96364E+01 | -1.04688E+01 |
| 220 | 3.98182E+01 | -3.04688E+01 |
| 221 | 4.00000E+01 | -1.04688E+01 |
| 222 | 4.01818E+01 | -5.04688E+01 |
| 223 | 4.03636E+01 | -7.04688E+01 |
| 224 | 4.05455E+01 | -7.04688E+01 |
| 225 | 4.07273E+01 | -7.04688E+01 |
| 226 | 4.09091E+01 | -9.04688E+01 |
| 227 | 4.10909E+01 | -7.04688E+01 |
| 228 | 4.12727E+01 | -7.04688E+01 |
| 229 | 4.14545E+01 | -7.04688E+01 |
| 230 | 4.16364E+01 | -5.04688E+01 |
| 231 | 4.18182E+01 | 2.95313E+01 |
| 232 | 4.20000E+01 | 8.95313E+01 |
| 233 | 4.21818E+01 | 8.95313E+01 |
| 234 | 4.23636E+01 | 6.95313E+01 |
| 235 | 4.25455E+01 | 1.09531E+02 |
| 236 | 4.27273E+01 | 8.95313E+01 |
| 237 | 4.29091E+01 | 6.95313E+01 |
| 238 | 4.30909E+01 | 6.95313E+01 |
| 239 | 4.32727E+01 | 4.95313E+01 |
| 240 | 4.34545E+01 | 4.95313E+01 |

TABLE V (Cont'd)

| | | |
|---|---|---|
| 241 | 4.36364E+01 | 4.95313E+01 |
| 242 | 4.38182E+01 | 4.95313E+01 |
| 243 | 4.40000E+01 | 4.95313E+01 |
| 244 | 4.41818E+01 | 9.53125E+00 |
| 245 | 4.43636E+01 | 9.53125E+00 |
| 246 | 4.45455E+01 | -1.04688E+01 |
| 247 | 4.47273E+01 | -3.04688E+01 |
| 248 | 4.49091E+01 | -3.04688E+01 |
| 249 | 4.50909E+01 | -1.04688E+01 |
| 250 | 4.52727E+01 | -5.04688E+01 |
| 251 | 4.54545E+01 | -3.04688E+01 |
| 252 | 4.56364E+01 | -3.04688E+01 |
| 253 | 4.58182E+01 | -5.04688E+01 |
| 254 | 4.60000E+01 | -7.04688E+01 |
| 255 | 4.61818E+01 | -5.04688E+01 |
| 256 | 4.63636E+01 | 9.53125E+00 |

# TABLE VI

## FREQUENCY DOMAIN DATA

REQUENCY WINDOW=0 TO 2.75000E+00[Hz]
EQUENCY INTERVAL= 2.14844E-02[Hz]

| COEFF. | FREQUENCY[Hz] | REAL | IMAG | MAGNITUDE | PHASE[DEG] |
|---|---|---|---|---|---|
| C TERM | 0.00000E+00 | 0.00000E+00 | | | |
| X FREQ. | 2.75000E+00 | 0.00000E+00 | | | |
| 1 | 2.14844E-02 | -7.02140E+00 | 8.31356E+00 | 1.08819E+01 | 130.18 |
| 2 | 4.29688E-02 | -4.53011E+00 | -1.49749E+01 | 1.56451E+01 | -106.83 |
| 3 | 6.44531E-02 | 8.78196E-01 | 5.80495E+00 | 5.87100E+00 | 81.40 |
| 4 | 8.59375E-02 | -9.52862E+00 | 5.35053E-01 | 9.54363E+00 | 176.79 |
| 5 | 1.07422E-01 | -2.28104E+01 | 8.23003E+00 | 2.42497E+01 | 160.16 |
| 6 | 1.28906E-01 | -1.63501E+01 | 2.52672E+01 | 3.00958E+01 | 122.91 |
| 7 | 1.50391E-01 | -1.65496E+00 | 1.09040E+01 | 1.10289E+01 | 98.63 |
| 8 | 1.71875E-01 | 3.46512E-01 | -1.04759E+01 | 1.04816E+01 | -88.11 |
| 9 | 1.93359E-01 | -5.83263E+00 | 1.88343E+00 | 6.12918E+00 | 162.10 |
| 10 | 2.14844E-01 | -6.56539E-01 | -2.47107E+01 | 2.47194E+01 | -91.52 |
| 11 | 2.36328E-01 | 6.56960E+00 | -9.28349E+00 | 1.13729E+01 | -54.71 |
| 12 | 2.57813E-01 | -2.60729E-01 | 8.83748E+00 | 8.84132E+00 | 91.69 |
| 13 | 2.79297E-01 | -3.14266E+00 | 8.46112E+00 | 9.02590E+00 | 110.38 |
| 14 | 3.00781E-01 | 1.54004E+01 | 7.51768E+00 | 1.71373E+01 | 26.02 |
| 15 | 3.22266E-01 | 6.85749E+00 | 2.43352E+00 | 7.27648E+00 | 19.54 |
| 16 | 3.43750E-01 | 5.24993E+00 | -9.23535E+00 | 1.06232E+01 | -60.38 |
| 17 | 3.65234E-01 | -1.25718E+01 | -4.87202E+00 | 1.34828E+01 | -158.82 |
| 18 | 3.86719E-01 | -9.12445E+00 | -5.73891E+00 | 1.07792E+01 | -147.83 |
| 19 | 4.08203E-01 | -7.38371E-01 | 3.94879E+00 | 4.01723E+00 | 100.59 |
| 20 | 4.29688E-01 | -3.87050E+00 | -2.95985E+00 | 4.87252E+00 | -142.59 |
| 21 | 4.51172E-01 | 5.43498E+00 | -1.81511E+00 | 5.73006E+00 | -18.47 |
| 22 | 4.72656E-01 | 4.24586E-01 | 8.19398E+00 | 8.20497E+00 | 87.03 |
| 23 | 4.94141E-01 | 3.52328E+00 | -5.78434E+00 | 6.77289E+00 | -58.65 |
| 24 | 5.15625E-01 | -4.05755E-01 | 6.19418E+00 | 6.20745E+00 | 93.75 |
| 25 | 5.37109E-01 | -3.94952E+00 | 9.56106E+00 | 1.03447E+01 | 112.44 |
| 26 | 5.58594E-01 | 1.31184E+00 | -4.68747E+00 | 4.86757E+00 | -74.37 |
| 27 | 5.80078E-01 | 9.93151E-01 | -6.96054E+00 | 7.03104E+00 | -81.88 |
| 28 | 6.01563E-01 | -6.59283E+00 | -2.18423E+00 | 6.94524E+00 | -161.67 |
| 29 | 6.23047E-01 | -3.50754E+00 | 8.64102E-01 | 3.61241E+00 | 166.16 |
| 30 | 6.44531E-01 | 9.14433E-01 | 5.95268E+00 | 6.02251E+00 | 81.27 |
| 31 | 6.66016E-01 | 2.98276E+00 | -3.61861E+00 | 4.68948E+00 | -50.50 |
| 32 | 6.87500E-01 | 3.02562E+00 | -6.10811E+00 | 6.81640E+00 | -63.65 |
| 33 | 7.08984E-01 | 1.44179E-01 | 4.98976E+00 | 4.99184E+00 | 88.34 |
| 34 | 7.30469E-01 | -4.57387E+00 | -4.50546E+00 | 6.42024E+00 | -135.43 |
| 35 | 7.51953E-01 | -1.92420E+00 | -5.23073E-01 | 1.99403E+00 | -164.79 |
| 36 | 7.73438E-01 | 6.19173E+00 | 7.60210E+00 | 9.80457E+00 | 50.84 |
| 37 | 7.94922E-01 | -2.14562E+00 | 1.04779E-01 | 2.14818E+00 | 177.20 |
| 38 | 8.16406E-01 | 1.09925E+00 | 6.99721E-01 | 1.30306E+00 | [illegible] |
| 39 | 8.37891E-01 | 1.06419E+00 | -2.09872E+00 | 2.35311E+00 | [illegible] |

## TABLE VI (Cont'd)

| | | | | | |
|---|---|---|---|---|---|
| 40 | [illegible] | -1.47818E+00 | -4.49089E+00 | [illegible] | [illegible] |
| 41 | 8.80859E-01 | 2.14066E+00 | -4.13356E+00 | 4.65497E+00 | -62.62 |
| 42 | 9.02344E-01 | 1.51962E+00 | 1.54043E+00 | 2.16383E+00 | 45.39 |
| 43 | 9.23828E-01 | -3.21545E+00 | 1.06439E+00 | 3.38704E+00 | 161.68 |
| 44 | 9.45313E-01 | -4.85195E+00 | -1.61634E-01 | 4.85464E+00 | -178.09 |
| 45 | 9.66797E-01 | -4.21918E+00 | -6.05999E-01 | 4.26248E+00 | -171.83 |
| 46 | 9.88281E-01 | -3.25301E+00 | 1.91562E+00 | 3.77514E+00 | 149.51 |
| 47 | 1.00977E+00 | -4.82362E+00 | -1.09172E-01 | 4.82485E+00 | -178.70 |
| 48 | 1.03125E+00 | 1.82595E+00 | 3.24752E+00 | 3.72565E+00 | 60.65 |
| 49 | 1.05273E+00 | -4.31825E-01 | 2.69930E+00 | 2.73362E+00 | 99.09 |
| 50 | 1.07422E+00 | 1.53275E-01 | -5.34120E-01 | 5.55677E-01 | -73.99 |
| 51 | [illegible] | 1.84387E+00 | 1.61757E+00 | 2.45283E+00 | [illegible] |
| 52 | [illegible] | -9.32933E-01 | 2.59941E+00 | 2.76176E+00 | [illegible] |
| 53 | 1.13867E+00 | -1.29609E+00 | -3.23155E+00 | 3.48178E+00 | -111.86 |
| 54 | 1.16016E+00 | 3.76591E-01 | 1.91414E+00 | 1.95084E+00 | 78.87 |
| 55 | 1.18164E+00 | -1.16508E+00 | 1.96309E+00 | 2.28279E+00 | 120.69 |
| 56 | 1.20313E+00 | -4.00404E+00 | 4.02544E+00 | 5.67772E+00 | 134.85 |
| 57 | 1.22461E+00 | -3.59129E+00 | 8.86039E-01 | 3.69897E+00 | 166.14 |
| 58 | 1.24609E+00 | 6.18702E-01 | 2.26769E+00 | 2.35058E+00 | 74.74 |
| 59 | 1.26758E+00 | 3.18393E+00 | -9.85305E-01 | 3.33290E+00 | -17.20 |
| 60 | 1.28906E+00 | 1.77718E-01 | 3.89440E-01 | 4.28074E-01 | 65.47 |
| 61 | 1.31055E+00 | 2.04796E-01 | 2.39098E+00 | 2.39974E+00 | 85.10 |
| 62 | 1.33203E+00 | -3.71906E-01 | 5.43294E-03 | 3.71945E-01 | 179.16 |
| 63 | 1.35352E+00 | -2.42373E+00 | 2.65463E+00 | 3.59466E+00 | 132.40 |
| 64 | 1.37500E+00 | 4.68750E-01 | 4.68750E-01 | 6.62913E-01 | 45.00 |
| 65 | 1.39648E+00 | 7.93919E-01 | 8.31793E-01 | 1.14986E+00 | 46.33 |
| 66 | 1.41797E+00 | -4.41786E+00 | 1.67257E+00 | 4.72387E+00 | 159.26 |
| 67 | 1.43945E+00 | -9.41065E-01 | 1.10211E+00 | 1.44922E+00 | 130.49 |
| 68 | 1.46094E+00 | -2.80306E+00 | -1.69564E-01 | 2.80818E+00 | -176.54 |
| 69 | 1.48242E+00 | 3.64787E-01 | 7.54600E-01 | 8.38148E-01 | 64.20 |
| 70 | 1.50391E+00 | -1.38463E+00 | 2.47770E+00 | 2.83834E+00 | 119.20 |
| 71 | 1.52539E+00 | -2.74257E-01 | 2.23734E+00 | 2.25409E+00 | 96.99 |
| 72 | 1.54688E+00 | 1.75796E-01 | 3.43704E+00 | 3.44153E+00 | 87.07 |
| 73 | 1.56836E+00 | 1.66749E+00 | 1.38267E+00 | 2.16618E+00 | 39.67 |
| 74 | 1.58984E+00 | -1.05343E+00 | 2.05064E+00 | 2.30540E+00 | 117.19 |
| 75 | 1.61133E+00 | -2.87200E+00 | 1.53089E+00 | 3.25453E+00 | 151.94 |
| 76 | 1.63281E+00 | 6.41357E-01 | 1.68072E+00 | 1.79893E+00 | 69.11 |
| 77 | 1.65430E+00 | -3.50697E+00 | -5.49277E-01 | 3.54973E+00 | -171.10 |
| 78 | 1.67578E+00 | -1.36506E+00 | -2.36373E+00 | 2.72958E+00 | [illegible] |
| 79 | 1.69727E+00 | -5.70852E-01 | 6.55152E-01 | 8.68963E-01 | [illegible] |

## TABLE VI (Cont'd)

| | | | | | |
|---|---|---|---|---|---|
| [illegible] | [illegible] | -1.09371E+00 | 2.20551E-01 | [illegible] | [illegible] |
| 81 | [illegible] | -7.75717E-01 | -5.49652E-01 | 9.50712E-01 | -144.68 |
| 82 | 1.76172E+00 | -3.24035E+00 | 9.46357E-01 | 3.37572E+00 | 163.72 |
| 83 | 1.78320E+00 | -2.37853E+00 | 2.97173E+00 | 3.80639E+00 | 128.67 |
| 84 | 1.80469E+00 | -4.19054E-02 | -1.16424E+00 | 1.16500E+00 | -92.06 |
| 85 | 1.82617E+00 | -1.53113E+00 | -1.10971E-01 | 1.53515E+00 | -175.85 |
| 86 | 1.84766E+00 | -1.06824E+00 | -1.35872E-01 | 1.07685E+00 | -172.75 |
| 87 | 1.86914E+00 | -1.85782E+00 | 3.59185E+00 | 4.04387E+00 | 117.35 |
| 88 | 1.89063E+00 | -8.93383E-01 | 3.05749E+00 | 3.18533E+00 | 106.29 |
| 89 | 1.91211E+00 | 6.91265E-01 | -9.10357E-01 | 1.14306E+00 | -52.79 |
| 90 | 1.93359E+00 | 1.13818E+00 | 1.23205E-01 | 1.14483E+00 | 6.18 |
| 91 | 1.95508E+00 | -1.81576E+00 | 5.90650E-01 | 1.90941E+00 | 161.98 |
| 92 | 1.97656E+00 | 6.02578E-01 | -1.98829E+00 | 2.07760E+00 | -73.14 |
| 93 | 1.99805E+00 | 4.35826E-01 | -3.30314E-01 | 5.46856E-01 | -37.16 |
| 94 | 2.01953E+00 | -4.83768E-01 | 3.33587E+00 | 3.37077E+00 | 98.25 |
| 95 | 2.04102E+00 | -1.64803E+00 | 2.62684E+00 | 3.10102E+00 | 122.10 |
| 96 | 2.06250E+00 | 1.03688E+00 | 1.41893E-01 | 1.04654E+00 | 7.79 |
| 97 | 2.08398E+00 | -7.11063E-01 | 6.32471E-01 | 9.51646E-01 | 138.35 |
| 98 | 2.10547E+00 | -1.90244E+00 | 2.00929E+00 | 2.76705E+00 | 133.44 |
| 99 | 2.12695E+00 | 1.08589E+00 | 1.12136E+00 | 1.56096E+00 | 45.92 |
| 100 | 2.14844E+00 | -9.53113E-01 | 2.79339E-01 | 9.93205E-01 | 163.67 |
| 101 | 2.16992E+00 | -4.82686E-01 | -5.71686E-01 | 7.48205E-01 | -130.18 |
| 102 | 2.19141E+00 | -4.59728E-01 | 6.07324E-01 | 7.61703E-01 | 127.12 |
| 103 | 2.21289E+00 | -2.15382E+00 | -3.47223E-02 | 2.15410E+00 | -179.08 |
| 104 | 2.23438E+00 | -5.30743E-01 | -8.32787E-02 | 5.37237E-01 | -171.08 |
| 105 | 2.25586E+00 | -9.58001E-01 | -1.17961E+00 | 1.51962E+00 | -129.08 |
| 106 | 2.27734E+00 | 8.45109E-01 | 2.72916E+00 | 2.85701E+00 | 72.79 |
| 107 | 2.29883E+00 | -1.57500E+00 | -1.35633E+00 | 2.07852E+00 | -139.27 |
| 108 | 2.32031E+00 | -1.70998E+00 | 2.19022E+00 | 2.77869E+00 | 127.98 |
| 109 | [illegible] | -1.43933E+00 | -1.62636E-01 | 1.44849E+00 | [illegible] |
| 110 | [illegible] | -6.05533E-01 | 5.70253E-01 | 8.31781E-01 | [illegible] |
| 111 | 2.38477E+00 | -7.81351E-01 | 2.23783E+00 | 2.37032E+00 | [illegible] |
| 112 | 2.40625E+00 | -9.82158E-01 | 8.62688E-01 | 1.30724E+00 | 138.71 |
| 113 | 2.42773E+00 | -1.55108E+00 | 1.02505E+00 | 1.85919E+00 | 146.54 |
| 114 | 2.44922E+00 | 2.99750E-01 | 1.65628E+00 | 1.68318E+00 | 79.74 |
| 115 | 2.47070E+00 | 2.30480E-01 | -1.73347E+00 | 1.74873E+00 | -82.43 |
| 116 | 2.49219E+00 | 1.54440E+00 | 4.47102E-01 | 1.60781E+00 | 16.15 |
| 117 | 2.51367E+00 | -3.02466E+00 | -1.10791E+00 | 3.22118E+00 | -159.88 |
| 118 | 2.53516E+00 | -1.90784E-01 | 3.37547E-01 | 3.87732E-01 | 119.48 |
| 119 | 2.55664E+00 | -9.15621E-01 | -1.26374E+00 | 1.56058E+00 | -125.92 |
| 120 | 2.57813E+00 | -7.10209E-01 | 1.09913E-01 | 7.18664E-01 | 171.20 |
| 121 | 2.59961E+00 | -7.43019E-01 | 4.73766E-01 | 8.81210E-01 | 147.48 |
| 122 | 2.62109E+00 | 5.97358E-01 | 1.74426E-01 | 6.22303E-01 | 16.28 |
| 123 | 2.64258E+00 | -1.20809E+00 | -6.64337E-01 | 1.37870E+00 | -151.19 |
| 124 | 2.66406E+00 | -1.12178E-01 | 9.05643E-01 | 9.12564E-01 | 97.06 |
| 125 | 2.68555E+00 | -9.86286E-01 | -5.38748E-01 | 1.12384E+00 | -151.35 |
| [illegible] | [illegible] | 3.32753E-01 | -1.27702E+00 | 1.31966E+00 | |
| [illegible] | [illegible] | 7.67470E-02 | -1.82571E+00 | 1.82732E+00 | |

## TABLE VII

### POWER

| COEFF. | FREQ.[Hz] | POWER | ( )/MAX |
|---|---|---|---|
| DC | 0.00000E+00 | 0.00000E+00 | 0.000 |
| MAX | 2.75000E+00 | 0.00000E+00 | 0.000 |
| 1 | 2.14844E-02 | 1.18415E+02 | .131 |
| 2 | 4.29688E-02 | 2.44768E+02 | .270 |
| 3 | 6.44531E-02 | 3.44687E+01 | .038 |
| 4 | 8.59375E-02 | 9.10808E+01 | .101 |
| 5 | 1.07422E-01 | 5.88049E+02 | .649 |
| 6 | 1.28906E-01 | 9.05759E+02 | 1.000 |
| 7 | 1.50391E-01 | 1.21636E+02 | .134 |
| 8 | 1.71875E-01 | 1.09864E+02 | .121 |
| 9 | 1.93359E-01 | 3.75669E+01 | .041 |
| 10 | 2.14844E-01 | 6.11050E+02 | .675 |
| 11 | 2.36328E-01 | 1.29343E+02 | .143 |
| 12 | 2.57813E-01 | 7.81690E+01 | .086 |
| 13 | 2.79297E-01 | 8.14669E+01 | .090 |
| 14 | 3.00781E-01 | 2.93687E+02 | .324 |
| 15 | 3.22266E-01 | 5.29472E+01 | .058 |
| 16 | 3.43750E-01 | 1.12853E+02 | .125 |
| 17 | 3.65234E-01 | 1.81786E+02 | .201 |
| 18 | 3.86719E-01 | 1.16191E+02 | .128 |
| 19 | 4.08203E-01 | 1.61381E+01 | .018 |
| 20 | 4.29688E-01 | 2.37415E+01 | .026 |
| 21 | 4.51172E-01 | 3.28336E+01 | .036 |
| 22 | 4.72656E-01 | 6.73215E+01 | .074 |
| 23 | 4.94141E-01 | 4.58721E+01 | .051 |
| 24 | 5.15625E-01 | 3.85324E+01 | .043 |
| 25 | 5.37109E-01 | 1.07013E+02 | .118 |
| 26 | 5.58594E-01 | 2.36933E+01 | .026 |
| 27 | 5.80078E-01 | 4.94355E+01 | .055 |
| 28 | 6.01563E-01 | 4.82363E+01 | .053 |
| 29 | 6.23047E-01 | 1.30495E+01 | .014 |
| 30 | 6.44531E-01 | 3.62706E+01 | .040 |
| 31 | 6.66016E-01 | 2.19912E+01 | .024 |
| 32 | 6.87500E-01 | 4.64633E+01 | .051 |
| 33 | 7.08984E-01 | 2.49135E+01 | .028 |
| 34 | 7.30469E-01 | 4.12194E+01 | .046 |
| 35 | 7.51953E-01 | 3.97614E+00 | .004 |
| 36 | 7.73438E-01 | 9.61296E+01 | .106 |
| 37 | 7.94922E-01 | 4.61467E+00 | .005 |
| 38 | 8.16406E-01 | 1.69797E+00 | .002 |
| 39 | 8.37891E-01 | 5.53715E+00 | .006 |

TABLE VII (Cont'd)

| | | | |
|---|---|---|---|
| [illegible] | [illegible]5E-01 | 2.23531E+01 | .025 |
| 41 | 8.80859E-01 | 2.16687E+01 | .024 |
| 42 | 9.02344E-01 | 4.68218E+00 | .005 |
| 43 | 9.23828E-01 | 1.14720E+01 | .013 |
| 44 | 9.45313E-01 | 2.35675E+01 | .026 |
| 45 | 9.66797E-01 | 1.81687E+01 | .020 |
| 46 | 9.88281E-01 | 1.42517E+01 | .016 |
| 47 | 1.00977E+00 | 2.32792E+01 | .026 |
| 48 | 1.03125E+00 | 1.38805E+01 | .015 |
| 49 | 1.05273E+00 | 7.47269E+00 | .008 |
| 50 | 1.07422E+00 | 3.08777E-01 | .000 |
| 51 | 1.09570E+00 | 6.01639E+00 | .007 |
| 52 | 1.11719E+00 | 7.62732E+00 | .008 |
| 53 | 1.13867E+00 | 1.21228E+01 | .013 |
| 54 | 1.16016E+00 | 3.80576E+00 | .004 |
| 55 | 1.18164E+00 | 5.21114E+00 | .006 |
| 56 | 1.20313E+00 | 3.22365E+01 | .036 |
| 57 | 1.22461E+00 | 1.36824E+01 | .015 |
| 58 | 1.24609E+00 | 5.52522E+00 | .006 |
| 59 | 1.26758E+00 | 1.11082E+01 | .012 |
| 60 | 1.28906E+00 | 1.83247E-01 | .000 |
| 61 | 1.31055E+00 | 5.75875E+00 | .006 |
| 62 | 1.33203E+00 | 1.38343E-01 | .000 |
| 63 | 1.35352E+00 | 1.29216E+01 | .014 |
| 64 | 1.37500E+00 | 4.39453E-01 | .000 |
| 65 | 1.39648E+00 | 1.32219E+00 | .001 |
| 66 | 1.41797E+00 | 2.23150E+01 | .025 |
| 67 | 1.43945E+00 | 2.10024E+00 | .002 |
| 68 | 1.46094E+00 | 7.88588E+00 | .009 |
| 69 | 1.48242E+00 | 7.02491E-01 | .001 |
| 70 | 1.50391E+00 | 8.05617E+00 | .009 |
| 71 | 1.52539E+00 | 5.08092E+00 | .006 |
| 72 | 1.54688E+00 | 1.18441E+01 | .013 |
| 73 | 1.56836E+00 | 4.69232E+00 | .005 |
| 74 | 1.58984E+00 | 5.31485E+00 | .006 |
| 75 | 1.61133E+00 | 1.05920E+01 | .012 |
| 76 | 1.63281E+00 | 3.23616E+00 | .004 |
| 77 | 1.65430E+00 | 1.26005E+01 | .014 |
| 78 | 1.67578E+00 | 7.45059E+00 | .008 |
| 79 | 1.69727E+00 | 7.55097E-01 | .001 |
| 80 | 1.71875E+00 | 1.24485E+00 | .001 |
| 81 | 1.74023E+00 | 9.03854E-01 | .001 |
| 82 | 1.76172E+00 | 1.13955E+01 | .013 |
| 83 | 1.78320E+00 | 1.44886E+01 | .016 |
| 84 | 1.80469E+00 | 1.35722E+00 | .001 |
| 85 | 1.82617E+00 | 2.35668E+00 | .003 |
| 86 | 1.84766E+00 | 1.15960E+00 | .001 |
| 87 | 1.86914E+00 | 1.63529E+01 | .018 |

## TABLE VII (Cont'd)

| | | | |
|---|---|---|---|
| [illegible] | [illegible] | 1.01464E+01 | [illegible] |
| 89 | 1.91211E+00 | 1.30660E+00 | .001 |
| 90 | 1.93359E+00 | 1.31063E+00 | .001 |
| 91 | 1.95508E+00 | 3.64585E+00 | .004 |
| 92 | 1.97656E+00 | 4.31641E+00 | .005 |
| 93 | 1.99805E+00 | 2.99051E-01 | .000 |
| 94 | 2.01953E+00 | 1.13621E+01 | .013 |
| 95 | 2.04102E+00 | 9.61632E+00 | .011 |
| 96 | 2.06250E+00 | 1.09526E+00 | .001 |
| 97 | 2.08398E+00 | 9.05631E-01 | .001 |
| 98 | 2.10547E+00 | 7.65656E+00 | .008 |
| 99 | 2.12695E+00 | 2.43661E+00 | .003 |
| 100 | 2.14844E+00 | 9.86455E-01 | .001 |
| 101 | 2.16992E+00 | 5.59811E-01 | .001 |
| 102 | 2.19141E+00 | 5.80192E-01 | .001 |
| 103 | 2.21289E+00 | 4.64016E+00 | .005 |
| 104 | 2.23438E+00 | 2.88624E-01 | .000 |
| 105 | 2.25586E+00 | 2.30924E+00 | .003 |
| 106 | 2.27734E+00 | 8.16251E+00 | .009 |
| 107 | 2.29883E+00 | 4.32025E+00 | .005 |
| 108 | 2.32031E+00 | 7.72112E+00 | .009 |
| 109 | 2.34180E+00 | 2.09812E+00 | .002 |
| 110 | 2.36328E+00 | 6.91860E-01 | .001 |
| 111 | 2.38477E+00 | 5.61841E+00 | .006 |
| 112 | [illegible] | 1.70886E+00 | .002 |
| 113 | [illegible] | 3.45658E+00 | .004 |
| 114 | [illegible] | 2.83311E+00 | .003 |
| 115 | 2.47070E+00 | 3.05805E+00 | .003 |
| 116 | 2.49219E+00 | 2.58507E+00 | .003 |
| 117 | 2.51367E+00 | 1.03760E+01 | .011 |
| 118 | 2.53516E+00 | 1.50336E-01 | .000 |
| 119 | 2.55664E+00 | 2.43540E+00 | .003 |
| 120 | 2.57813E+00 | 5.16478E-01 | .001 |
| 121 | 2.59961E+00 | 7.76531E-01 | .001 |
| 122 | 2.62109E+00 | 3.87261E-01 | .000 |
| 123 | 2.64258E+00 | 1.90081E+00 | .002 |
| 124 | 2.66406E+00 | 8.32774E-01 | .001 |
| 125 | 2.68555E+00 | 1.26301E+00 | .001 |
| 126 | [illegible] | 1.74151E+00 | .002 |
| 127 | [illegible] | 3.33910E+00 | .004 |

# TABLE VIII

| # | X | Y | # | X | Y |
|---|---|---|---|---|---|
| 1 | 19000 | 0 | 2 | 19060 | 0 |
| 3 | 19180 | 0 | 4 | 19100 | 0 |
| 5 | 18940 | 0 | 6 | 18900 | 0 |
| 7 | 18840 | 0 | 8 | 18780 | 0 |
| 9 | 18720 | 0 | 10 | 18560 | 0 |
| 11 | 18440 | 0 | 12 | 18840 | 0 |
| 13 | 19140 | 0 | 14 | 19220 | 0 |
| 15 | 19340 | 0 | 16 | 19360 | 0 |
| 17 | 19200 | 0 | 18 | 18960 | 0 |
| 19 | 18980 | 0 | 20 | 19160 | 0 |
| 21 | 19100 | 0 | 22 | 19180 | 0 |
| 23 | 19180 | 0 | 24 | 19100 | 0 |
| 25 | 19020 | 0 | 26 | 19020 | 0 |
| 27 | 18860 | 0 | 28 | 18880 | 0 |
| 29 | 19180 | 0 | 30 | 19280 | 0 |
| 31 | 19340 | 0 | 32 | 19280 | 0 |
| 33 | 19220 | 0 | 34 | 19100 | 0 |
| 35 | 18940 | 0 | 36 | 19000 | 0 |
| 37 | 19180 | 0 | 38 | 19120 | 0 |
| 39 | 19000 | 0 | 40 | 19060 | 0 |
| 41 | 19060 | 0 | 42 | 18880 | 0 |
| 43 | 18680 | 0 | 44 | 18700 | 0 |
| 45 | 18680 | 0 | 46 | 18780 | 0 |
| 47 | 19040 | 0 | 48 | 19260 | 0 |
| 49 | 19200 | 0 | 50 | 19020 | 0 |
| 51 | 18740 | 0 | 52 | 18440 | 0 |
| 53 | 18320 | 0 | 54 | 18400 | 0 |
| 55 | 18600 | 0 | 56 | 18720 | 0 |
| 57 | 18900 | 0 | 58 | 19020 | 0 |
| 59 | 18860 | 0 | 60 | 18620 | 0 |
| 61 | 18840 | 0 | 62 | 19160 | 0 |
| 63 | 19260 | 0 | 64 | 19260 | 0 |
| 65 | 19240 | 0 | 66 | 19400 | 0 |
| 67 | 19280 | 0 | 68 | 19040 | 0 |
| 69 | 19040 | 0 | 70 | 19280 | 0 |
| 71 | 19400 | 0 | 72 | 19360 | 0 |
| 73 | 19180 | 0 | 74 | 18940 | 0 |
| 75 | 19000 | 0 | 76 | 18940 | 0 |
| 77 | 19160 | 0 | 78 | 18960 | 0 |
| 79 | 18980 | 0 | 80 | 18980 | 0 |
| 81 | 18740 | 0 | 82 | 18840 | 0 |
| 83 | 19020 | 0 | 84 | 19300 | 0 |
| 85 | 19260 | 0 | 86 | 19240 | 0 |
|  | 9400 | 0 | 88 | 1936 |  |
|  | 9080 | 0 | 90 | 1910 |  |

## TABLE VIII (Cont'd)

| | | | | | |
|---|---|---|---|---|---|
| | 19240 | 0 | 92 | 19 | |
| 93 | 19160 | 0 | 94 | 18960 | |
| 95 | 19080 | 0 | 96 | 19020 | 0 |
| 97 | 18980 | 0 | 98 | 19200 | 0 |
| 99 | 19320 | 0 | 100 | 19280 | 0 |
| 101 | 19080 | 0 | 102 | 18940 | 0 |
| 103 | 18760 | 0 | 104 | 18660 | 0 |
| 105 | 18600 | 0 | 106 | 18600 | 0 |
| | 18520 | 0 | 108 | 18660 | |
| | 18760 | 0 | 110 | 18580 | |
| | 18540 | 0 | 112 | 18600 | |
| 113 | 18540 | 0 | 114 | 18460 | 0 |
| 115 | 18560 | 0 | 116 | 18760 | 0 |
| 117 | 18980 | 0 | 118 | 18980 | 0 |
| 119 | 18840 | 0 | 120 | 18740 | 0 |
| 121 | 18720 | 0 | 122 | 18760 | 0 |
| 123 | 18700 | 0 | 124 | 19040 | 0 |
| 125 | 19040 | 0 | 126 | 19180 | 0 |
| 127 | 19280 | 0 | 128 | 19140 | 0 |
| 129 | 19100 | 0 | 130 | 19060 | 0 |
| 131 | 19300 | 0 | 132 | 19040 | 0 |
| 133 | 18760 | 0 | 134 | 18900 | 0 |
| 135 | 19020 | 0 | 136 | 19220 | 0 |
| 137 | 19220 | 0 | 138 | 19200 | 0 |
| 139 | 19100 | 0 | 140 | 19320 | 0 |
| 141 | 19400 | 0 | 142 | 19440 | 0 |
| 143 | 19460 | 0 | 144 | 19380 | 0 |
| 145 | 19280 | 0 | 146 | 19160 | 0 |
| 147 | 19080 | 0 | 148 | 19140 | 0 |
| 149 | 18940 | 0 | 150 | 18780 | 0 |
| 151 | 18820 | 0 | 152 | 18880 | 0 |
| 153 | 18940 | 0 | 154 | 19140 | 0 |
| 155 | 19260 | 0 | 156 | 19320 | 0 |
| 157 | 19280 | 0 | 158 | 19140 | 0 |
| 159 | 19020 | 0 | 160 | 18880 | 0 |
| 161 | 18540 | 0 | 162 | 18520 | 0 |
| 163 | 18880 | 0 | 164 | 19220 | 0 |
| 165 | 19160 | 0 | 166 | 19140 | 0 |
| 167 | 19240 | 0 | 168 | 19200 | 0 |
| 169 | 19360 | 0 | 170 | 19340 | 0 |
| 171 | 19340 | 0 | 172 | 19180 | 0 |
| 173 | 19140 | 0 | 174 | 19280 | 0 |
| 175 | 19160 | 0 | 176 | 18800 | 0 |
| | 3720 | 0 | 178 | 1898 | |
| | 3940 | 0 | 180 | 1902 | |

# TABLE VIII (Cont'd)

| | | | | | |
|---|---|---|---|---|---|
| 183 | [illegible] | | [illegible] | [illegible] | 0 |
| 185 | 19380 | [illegible] | 186 | 19180 | 0 |
| 187 | 18900 | 0 | 188 | 19000 | 0 |
| 189 | 19280 | 0 | 190 | 19300 | 0 |
| 191 | 19280 | 0 | 192 | 19200 | 0 |
| 193 | 19080 | 0 | 194 | 18780 | 0 |
| 195 | 18700 | 0 | 196 | 18780 | 0 |
| 197 | 18960 | 0 | 198 | 19060 | 0 |
| 199 | 19220 | 0 | 200 | 19280 | 0 |
| 201 | 19220 | 0 | 202 | 19160 | 0 |
| 203 | 19120 | 0 | 204 | 18820 | 0 |
| 205 | 18920 | 0 | 206 | 18820 | 0 |
| 207 | 19100 | 0 | 208 | 19180 | 0 |
| 209 | 19340 | 0 | 210 | 19160 | 0 |
| 211 | 19080 | 0 | 212 | 18960 | 0 |
| 213 | 18700 | 0 | 214 | 18680 | 0 |
| 215 | 18920 | 0 | 216 | 19020 | 0 |
| 217 | 18960 | 0 | 218 | 18940 | 0 |
| 219 | 19040 | 0 | 220 | 19160 | 0 |
| 221 | 19060 | 0 | 222 | 18940 | 0 |
| 223 | 19020 | 0 | 224 | 19100 | 0 |
| 225 | 19180 | 0 | 226 | 19180 | 0 |
| 227 | 19120 | 0 | 228 | 19140 | 0 |
| 229 | 19240 | 0 | 230 | 19140 | 0 |
| 231 | 19100 | 0 | 232 | 19180 | 0 |
| [illegible] | [illegible] | 0 | 234 | [illegible] | 0 |
| [illegible] | [illegible] | 0 | 236 | [illegible] | [illegible] |
| [illegible] | [illegible] | 0 | 238 | [illegible] | [illegible] |
| 239 | [illegible] | 0 | 240 | 19040 | 0 |
| 241 | 19120 | 0 | 242 | 19000 | 0 |
| 243 | 19140 | 0 | 244 | 19100 | 0 |
| 245 | 19020 | 0 | 246 | 18940 | 0 |
| 247 | 18820 | 0 | 248 | 18560 | 0 |
| 249 | 18360 | 0 | 250 | 18440 | 0 |
| 251 | 18740 | 0 | 252 | 19140 | 0 |
| [illegible] | [illegible] | 0 | 254 | 19100 | 0 |
| [illegible] | [illegible] | 0 | 256 | 18940 | [illegible] |

## TABLE IX

## RPM UNSTEADY COMPONENT AT 19000 RPM

```
AVG =                19016.484375


-16.484375           163.515625          -76.484375          -176.484375
-296.484375         -576.484375           123.515625          323.515625
 183.515625         -36.484375            83.515625           163.515625
 3.515625           -156.484375           163.515625          323.515625
 203.515625         -76.484375            163.515625         -16.484375
 43.515625          -336.484375          -336.484375          23.515625
 183.515625         -276.484375          -696.484375         -416.484375
-116.484375         -156.484375          -176.484375          243.515625
 223.515625          263.515625           23.515625           383.515625
 163.515625         -16.484375            143.515625         -36.484375
-276.484375          3.515625             243.515625          383.515625
 63.515625           223.515625           143.515625          63.515625
-36.484375           303.515625           63.515625          -256.484375
-416.484375         -496.484375          -256.484375         -476.484375
-476.484375         -456.484375          -36.484375          -176.484375
-296.484375         -316.484375           23.515625           263.515625
 83.515625           283.515625          -256.484375          3.515625
 203.515625          83.515625            383.515625          443.515625
 263.515625          63.515625           -76.484375          -196.484375
-76.484375           243.515625           263.515625          3.515625
-476.484375         -136.484375           143.515625          223.515625
 343.515625          323.515625           123.515625          143.515625
-296.484375         -76.484375           -136.484375         -176.484375
 363.515625         -116.484375           263.515625          263.515625
 63.515625          -316.484375          -56.484375           203.515625
 203.515625          103.515625          -96.484375           83.515625
 323.515625          63.515625           -316.484375         -96.484375
-56.484375           23.515625            43.515625           3.515625
 163.515625          103.515625           223.515625          83.515625
 203.515625          103.515625          -216.484375          83.515625
 103.515625          123.515625           3.515625           -196.484375
-656.484375         -276.484375           223.515625          63.515625
 43.515625           83.515625           -116.484375         -236.484375
-456.484375         -176.484375           203.515625          343.515625
-56.484375           143.515625           163.515625          83.515625
 3.515625           -136.484375           263.515625          263.515625
 83.515625          -16.484375            103.515625          43.515625
-136.484375         -316.484375          -236.484375          243.515625
```

## TABLE IX (Cont'd)

| | | | |
|---|---|---|---|
| 3.515625 | -576.484375 | -616.484375 | -296.484375 |
| 3.515625 | -396.484375 | 143.515625 | 243.515625 |
| 383.515625 | 23.515625 | 263.515625 | 343.515625 |
| -76.484375 | -76.484375 | -56.484375 | -36.484375 |
| -176.484375 | 283.515625 | 223.515625 | 343.515625 |
| 83.515625 | 223.515625 | -56.484375 | 3.515625 |
| 183.515625 | 263.515625 | -76.484375 | -356.484375 |
| -416.484375 | -356.484375 | -436.484375 | -416.484375 |
| -556.484375 | -256.484375 | -36.484375 | -276.484375 |
| -256.484375 | 23.515625 | 163.515625 | 123.515625 |
| 43.515625 | 23.515625 | -116.484375 | 203.515625 |
| 183.515625 | 303.515625 | 423.515625 | 363.515625 |
| 143.515625 | 123.515625 | -236.484375 | -136.484375 |
| 123.515625 | 303.515625 | 123.515625 | -136.484375 |
| -496.484375 | 203.515625 | 123.515625 | 183.515625 |
| 323.515625 | 163.515625 | 263.515625 | -216.484375 |
| -36.484375 | 3.515625 | -156.484375 | 63.515625 |
| 163.515625 | -16.484375 | 283.515625 | 183.515625 |
| -236.484375 | -236.484375 | 43.515625 | 263.515625 |
| 143.515625 | -196.484375 | -196.484375 | 163.515625 |
| 143.515625 | -56.484375 | -336.484375 | 3.515625 |
| -76.484375 | 143.515625 | -76.484375 | 83.515625 |
| 163.515625 | 123.515625 | 123.515625 | 163.515625 |
| 163.515625 | 103.515625 | -216.484375 | 23.515625 |
| -16.484375 | 83.515625 | -76.484375 | -456.484375 |
| -576.484375 | 123.515625 | 83.515625 | -76.484375 |

# TABLE X

## TIME DOMAIN DATA

```
NUMBER OF DATA POINTS =  256
TIME=0 TO  4.65455E+01[SEC]
TIME INTERVAL= 1.81818E-01[SEC]

    DATA POINT         TIME[SEC]              DATA
         1           0.00000E+00          -1.64844E+01
         2           1.81818E-01           4.35156E+01
         3           3.63636E-01           1.63516E+02
         4           5.45455E-01           8.35156E+01
         5           7.27273E-01          -7.64844E+01
         6           9.09091E-01          -1.16484E+02
         7           1.09091E+00          -1.76484E+02
         8           1.27273E+00          -2.36484E+02

         9           1.45455E+00          -2.96484E+02
        10           1.63636E+00          -4.56484E+02
        11           1.81818E+00          -5.76484E+02
        12           2.00000E+00          -1.76484E+02
        13           2.18182E+00           1.23516E+02
        14           2.36364E+00           2.03516E+02
        15           2.54545E+00           3.23516E+02
        16           2.72727E+00           3.43516E+02

        17           2.90909E+00           1.83516E+02
        18           3.09091E+00          -5.64844E+01
        19           3.27273E+00          -3.64844E+01
        20           3.45455E+00           1.43516E+02
        21           3.63636E+00           8.35156E+01
        22           3.81818E+00           1.63516E+02
        23           4.00000E+00           1.63516E+02
        24           4.18182E+00           8.35156E+01

        25           4.36364E+00           3.51563E+00
        26           4.54545E+00           3.51563E+00
        27           4.72727E+00          -1.56484E+02
        28           4.90909E+00          -1.36484E+02
        29           5.09091E+00           1.63516E+02
        30           5.27273E+00           2.63516E+02
        31           5.45455E+00           3.23516E+02
        32           5.63636E+00           2.63516E+02

        33           5.81818E+00           2.03516E+02
        34           6.00000E+00           8.35156E+01
        35           6.18182E+00          -7.64844E+01
        36           6.36364E+00          -1.64844E+01
        37           6.54545E+00           1.63516E+02
        38           6.72727E+00           1.03516E+02
        39           6.90909E+00          -1.64844E+01
        40           7.09091E+00           4.35156E+01
```

TABLE X (Cont'd)

| | | |
|---|---|---|
| 41 | 7.27273E+00 | 4.35156E+01 |
| 42 | 7.45455E+00 | -1.36484E+02 |
| 43 | 7.63636E+00 | -3.36484E+02 |
| 44 | 7.81818E+00 | -3.16484E+02 |
| 45 | 8.00000E+00 | -3.36484E+02 |
| 46 | 8.18182E+00 | -2.36484E+02 |
| 47 | 8.36364E+00 | 2.35156E+01 |
| 48 | 8.54545E+00 | 2.43516E+02 |
| 49 | 8.72727E+00 | 1.83516E+02 |
| 50 | 8.90909E+00 | 3.51563E+00 |
| 51 | 9.09091E+00 | -2.76484E+02 |
| 52 | 9.27273E+00 | -5.76484E+02 |
| 53 | 9.45455E+00 | -6.96484E+02 |
| 54 | 9.63636E+00 | -6.16484E+02 |
| 55 | 9.81818E+00 | -4.16484E+02 |
| 56 | 1.00000E+01 | -2.96484E+02 |
| 57 | 1.01818E+01 | -1.16484E+02 |
| 58 | 1.03636E+01 | 3.51563E+00 |
| 59 | 1.05455E+01 | -1.56484E+02 |
| 60 | 1.07273E+01 | -3.96484E+02 |
| 61 | 1.09091E+01 | -1.76484E+02 |
| 62 | 1.10909E+01 | 1.43516E+02 |
| 63 | 1.12727E+01 | 2.43516E+02 |
| 64 | 1.14545E+01 | 2.43516E+02 |
| 65 | 1.16364E+01 | 2.23516E+02 |
| 66 | 1.18182E+01 | 3.83516E+02 |
| 67 | 1.20000E+01 | 2.63516E+02 |
| 68 | 1.21818E+01 | 2.35156E+01 |
| 69 | 1.23636E+01 | 2.35156E+01 |
| 70 | 1.25455E+01 | 2.63516E+02 |
| 71 | 1.27273E+01 | 3.83516E+02 |
| 72 | 1.29091E+01 | 3.43516E+02 |
| 73 | 1.30909E+01 | 1.63516E+02 |
| 74 | 1.32727E+01 | -7.64844E+01 |
| 75 | 1.34545E+01 | -1.64844E+01 |
| 76 | 1.36364E+01 | -7.64844E+01 |
| 77 | 1.38182E+01 | 1.43516E+02 |
| 78 | 1.40000E+01 | -5.64844E+01 |
| 79 | 1.41818E+01 | -3.64844E+01 |
| 80 | 1.43636E+01 | -3.64844E+01 |

TABLE X (Cont'd)

| | | |
|---|---|---|
| 81 | 1.45455E+01 | -2.76484E+02 |
| 82 | 1.47273E+01 | -1.76484E+02 |
| 83 | 1.49091E+01 | 3.51563E+00 |
| 84 | 1.50909E+01 | 2.83516E+02 |
| 85 | 1.52727E+01 | 2.43516E+02 |
| 86 | 1.54545E+01 | 2.23516E+02 |
| 87 | 1.56364E+01 | 3.83516E+02 |
| 88 | 1.58182E+01 | 3.43516E+02 |
| 89 | 1.60000E+01 | 6,35156E+01 |
| 90 | 1.61818E+01 | 8,35156E+01 |
| 91 | 1.63636E+01 | 2.23516E+02 |
| 92 | 1,65455E+01 | 2,23516E+02 |
| 93 | 1,67273E+01 | 1.43516E+02 |
| 94 | 1.69091E+01 | -5.64844E+01 |
| 95 | 1.70909E+01 | 6.35156E+01 |
| 96 | 1.72727E+01 | 3,51563E+00 |
| 97 | 1.74545E+01 | -3.64844E+01 |
| 98 | 1.76364E+01 | 1,83516E+02 |
| 99 | 1.78182E+01 | 3.03516E+02 |
| 100 | 1.80000E+01 | 2.63516E+02 |
| 101 | 1.81818E+01 | 6.35156E+01 |
| 102 | 1.83636E+01 | -7.64844E+01 |
| 103 | 1.85455E+01 | -2.56484E+02 |
| 104 | 1.87273E+01 | -3.56484E+02 |
| 105 | 1.89091E+01 | -4.16484E+02 |
| 106 | 1,90909E+01 | -4.16484E+02 |
| 107 | 1.92727E+01 | -4.96484E+02 |
| 108 | 1.94545E+01 | -3.56484E+02 |
| 109 | 1.96364E+01 | -2.56484E+02 |
| 110 | 1.98182E+01 | -4.36484E+02 |
| 111 | 2.00000E+01 | -4.76484E+02 |
| 112 | 2.01818E+01 | -4.16484E+02 |
| 113 | 2.03636E+01 | -4.76484E+02 |
| 114 | 2.05455E+01 | -5.56484E+02 |
| 115 | 2.07273E+01 | -4.56484E+02 |
| 116 | 2,09091E+01 | -2.56484E+02 |
| 117 | 2.10909E+01 | -3.64844E+01 |
| 118 | 2,12727E+01 | -3.64844E+01 |
| 119 | 2.14545E+01 | -1,76484E+02 |
| 120 | 2.16364E+01 | -2.76484E+02 |
| 121 | 2,18182E+01 | -2.96484E+02 |
| 122 | 2,20000E+01 | -2.56484E+02 |
| 123 | 2,21818E+01 | -3.16484E+02 |
| 124 | 2.23636E+01 | 2.35156E+01 |
| 125 | 2.25455E+01 | 2.35156E+01 |
| 126 | 2.27273E+01 | 1.63516E+02 |
| 127 | 2.29091E+01 | 2.63516E+02 |
| 128 | 2.30909E+01 | 1.63516E+02 |

TABLE X (Cont'd)

| | | |
|---|---|---|
| [illegible] | [illegible] | [illegible] |
| 130 | 2.34545E+01 | [illegible] |
| 131 | [illegible] | 2.83516E+02 |
| 132 | 2,38182E+01 | 2.35156E+01 |
| 133 | 2.40000E+01 | -2.56484E+02 |
| 134 | 2.41818E+01 | -1.16484E+02 |
| 135 | 2.43636E+01 | 3.51563E+00 |
| 136 | 2.45455E+01 | 2.03516E+02 |
| 137 | 2.47273E+01 | 2.03516E+02 |
| 138 | 2.49091E+01 | 1,83516E+02 |
| 139 | 2,50909E+01 | 8,35156E+01 |
| 140 | 2,52727E+01 | 3.03516E+02 |
| 141 | 2.54545E+01 | 3.83516E+02 |
| 142 | 2,56364E+01 | 4.23516E+02 |
| 143 | 2,58182E+01 | 4,43516E+02 |
| 144 | 2.60000E+01 | 3.63516E+02 |
| 145 | 2.61818E+01 | 2.63516E+02 |
| 146 | 2,63636E+01 | 1.43516E+02 |
| 147 | 2,65455E+01 | 6.35156E+01 |
| 148 | 2,67273E+01 | 1,23516E+02 |
| 149 | 2.69091E+01 | -7,64844E+01 |
| 150 | 2.70909E+01 | -2,36484E+02 |
| 151 | 2.72727E+01 | -1,96484E+02 |
| 152 | 2.74545E+01 | -1,36484E+02 |
| 153 | 2.76364E+01 | -7.64844E+01 |
| 154 | 2,78182E+01 | 1,23516E+02 |
| 155 | 2,80000E+01 | 2,43516E+02 |
| 156 | 2.81818E+01 | 3,03516E+02 |
| 157 | 2.83636E+01 | 2,63516E+02 |
| 158 | 2.85455E+01 | 1.23516E+02 |
| 159 | 2.87273E+01 | 3.51563E+00 |
| 160 | 2.89091E+01 | -1,36484E+02 |
| 161 | 2.90909E+01 | -4.76484E+02 |
| 162 | 2.92727E+01 | -4,96484E+02 |
| 163 | 2,94545E+01 | -1,36484E+02 |
| 164 | 2.96364E+01 | 2.03516E+02 |
| 165 | 2,98182E+01 | 1,43516E+02 |
| 166 | 3.00000E+01 | 1,23516E+02 |
| 167 | 3.01818E+01 | 2,23516E+02 |
| 168 | 3,03636E+01 | 1,83516E+02 |
| 169 | 3.05455E+01 | 3.43516E+02 |
| 170 | 3.07273E+01 | 3,23516E+02 |

## TABLE X (Cont'd)

| | | |
|---|---|---|
| [illegible] | [illegible] | [illegible] |
| 172 | [illegible] | [illegible] |
| 173 | 3.12727E+01 | 1.23516E+02 |
| 174 | 3.14545E+01 | 2.63516E+02 |
| 175 | 3.16364E+01 | 1.43516E+02 |
| 176 | 3.18182E+01 | -2.16484E+02 |
| 177 | 3.20000E+01 | -2.96484E+02 |
| 178 | 3.21818E+01 | -3.64844E+01 |
| 179 | 3.23636E+01 | -7.64844E+01 |
| 180 | 3.25455E+01 | 3.51563E+00 |
| 181 | 3.27273E+01 | -1.36484E+02 |
| 182 | 3.29091E+01 | -1.56484E+02 |
| 183 | 3.30909E+01 | -1.76484E+02 |
| 184 | 3.32727E+01 | 6.35156E+01 |
| 185 | 3.34545E+01 | 3.63516E+02 |
| 186 | 3.36364E+01 | 1.63516E+02 |
| 187 | 3.38182E+01 | -1.16484E+02 |
| 188 | 3.40000E+01 | -1.64844E+01 |
| 189 | 3.41818E+01 | 2.63516E+02 |
| 190 | 3.43636E+01 | 2.83516E+02 |
| 191 | 3.45455E+01 | 2.63516E+02 |
| 192 | 3.47273E+01 | 1.83516E+02 |
| 193 | 3.49091E+01 | 6.35156E+01 |
| 194 | 3.50909E+01 | -2.36484E+02 |
| 195 | 3.52727E+01 | -3.16484E+02 |
| 196 | 3.54545E+01 | -2.36484E+02 |
| 197 | 3.56364E+01 | -5.64844E+01 |
| 198 | 3.58182E+01 | 4.35156E+01 |
| 199 | 3.60000E+01 | 2.03516E+02 |
| 200 | 3.61818E+01 | 2.63516E+02 |
| 201 | 3.63636E+01 | 2.03516E+02 |
| 202 | 3.65455E+01 | 1.43516E+02 |
| 203 | 3.67273E+01 | 1.03516E+02 |
| 204 | 3.69091E+01 | -1.96484E+02 |
| 205 | 3.70909E+01 | -9.64844E+01 |
| 206 | 3.72727E+01 | -1.96484E+02 |
| 207 | 3.74545E+01 | 8.35156E+01 |
| 208 | 3.76364E+01 | 1.63516E+02 |
| 209 | 3.78182E+01 | 3.23516E+02 |
| 210 | 3.80000E+01 | 1.43516E+02 |
| 211 | 3.81818E+01 | 6.35156E+01 |
| 212 | 3.83636E+01 | -5.64844E+01 |
| 213 | 3.85455E+01 | -3.16484E+02 |
| 214 | 3.87273E+01 | -3.36484E+02 |
| 215 | 3.89091E+01 | -9.64844E+01 |
| [illegible] | 3.90909E+01 | 3.51563E+00 |

## TABLE X (Cont'a)

| | | |
|---|---|---|
| [illegible] | .92727E+01 | [illegible] |
| [illegible] | .94545E+01 | -7.64844E+01 |
| 219 | 3.96364E+01 | 2.35156E+01 |
| 220 | 3.98182E+01 | 1.43516E+02 |
| 221 | 4.00000E+01 | 4.35156E+01 |
| 222 | 4.01818E+01 | -7.64844E+01 |
| 223 | 4.03636E+01 | 3.51563E+00 |
| 224 | 4.05455E+01 | 8.35156E+01 |
| 225 | 4.07273E+01 | 1.63516E+02 |
| 226 | 4.09091E+01 | 1.63516E+02 |
| 227 | 4.10909E+01 | 1.03516E+02 |
| 228 | 4.12727E+01 | 1.23516E+02 |
| 229 | 4.14545E+01 | 2.23516E+02 |
| 230 | 4.16364E+01 | 1.20516E+02 |
| 231 | 4.18182E+01 | 8.35156E+01 |
| 232 | 4.20000E+01 | 1.63516E+02 |
| 233 | 4.21818E+01 | 2.03516E+02 |
| 234 | 4.23636E+01 | 1.63516E+02 |
| 235 | 4.25455E+01 | 1.03516E+02 |
| 236 | 4.27273E+01 | 1.03516E+02 |
| 237 | 4.29091E+01 | -2.16484E+02 |
| 238 | 4.30909E+01 | -2.16484E+02 |
| 239 | 4.32727E+01 | 8.35156E+01 |
| 240 | 4.34545E+01 | 2.35156E+01 |
| 241 | 4.36364E+01 | 1.03516E+02 |
| 242 | 4.38182E+01 | -1.64844E+01 |
| 243 | 4.40000E+01 | 1.23516E+02 |
| 244 | 4.41818E+01 | 8.35156E+01 |
| 245 | 4.43636E+01 | 3.51563E+00 |
| 246 | 4.45455E+01 | -7.64844E+01 |
| 247 | 4.47273E+01 | -1.96484E+02 |
| 248 | 4.49091E+01 | -4.56484E+02 |
| 249 | 4.50909E+01 | -6.56484E+02 |
| 250 | 4.52727E+01 | -5.76484E+02 |
| 251 | 4.54545E+01 | -2.76484E+02 |
| 252 | 4.56364E+01 | 1.23516E+02 |
| 253 | 4.58182E+01 | 2.23516E+02 |
| 254 | 4.60000E+01 | 8.35156E+01 |
| 255 | 4.61818E+01 | 6.35156E+01 |
| 256 | 4.63636E+01 | -7.64844E+01 |

## TABLE XI

```
                              FREQUENCY DOMAIN DATA

FREQUENCY WINDOW=0 TO 2.75000E+00[Hz]
FREQUENCY INTERVAL= 2.14844E-02[Hz]

 COEFF.    FREQUENCY[Hz]      REAL           IMAG           MAGNITUDE     PHASE[DEG]
 DC TERM   0.00000E+00     0.00000E+00
MAX FREQ.  2.75000E+00     1.64063E+00
     1     2.14844E-02    -5.66422E+00     3.75558E+01     3.79806E+01        98.58
     2     4.29688E-02    -3.08013E+01    -2.76514E+01     4.13923E+01      -138.08
     3     6.44531E-02     2.52530E+01     4.37340E+01     5.05013E+01        60.00
     4     8.59375E-02    -2.67731E+01    -1.03771E+02     1.07169E+02      -104.47
     5     1.07422E-01    -9.72249E+01     4.94728E+01     1.09088E+02       153.03
     6     1.28906E-01    -4.04381E-01    -1.98008E+01     1.98049E+01       -91.17
     7     1.50391E-01    -3.17996E+01     3.81944E+01     4.96994E+01       129.78

     8     1.71875E-01     6.22003E+01    -3.24024E+01     7.01341E+01       -27.52
     9     1.93359E-01     1.60624E+01    -4.56514E+01     4.83947E+01       -70.62
    10     2.14844E-01    -3.48545E+01     4.23113E+01     5.48186E+01       129.48
    11     2.36328E-01     4.79565E+01     8.04794E+00     4.86271E+01         9.53
    12     2.57813E-01     3.00145E+01     2.77462E+01     4.08745E+01        42.75
    13     2.79297E-01    -1.09342E+01    -1.82064E+01     2.12375E+01      -120.99
    14     3.00781E-01     1.86397E+00    -1.25242E-01     1.86817E+00        -3.84
    15     3.22266E-01     7.79157E+01     1.78681E+01     7.99382E+01        12.92

    16     3.43750E-01     4.06294E+01     2.48508E+01     4.76268E+01        31.45
    17     3.65234E-01     1.12258E+01    -4.68472E+01     4.81734E+01       -76.52
    18     3.86719E-01     8.33142E+01    -3.20249E+00     8.33757E+01        -2.20
    19     4.08203E-01    -3.78938E+01    -1.55635E+01     4.09653E+01      -157.67
    20     4.29688E-01     3.54221E+01     1.61486E+01     3.89295E+01        24.51
    21     4.51172E-01     2.32465E+01     1.76307E+01     2.91760E+01        37.18
    22     4.72656E-01     2.12603E+01    -2.89151E+01     3.58899E+01       -53.67
    23     4.94141E-01     1.21275E+01     2.76710E+01     3.02119E+01        66.33

    24     5.15625E-01    -3.41449E+01     1.82663E+01     3.87238E+01       151.85
    25     5.37109E-01    -4.57706E+01    -1.16202E+01     4.72226E+01      -165.75
    26     5.58594E-01     1.17901E+01     2.11305E+01     2.41972E+01        60.84
    27     5.80078E-01     2.17012E+00    -2.70234E+01     2.71103E+01       -85.41
    28     6.01563E-01     1.88617E+00     2.44577E+01     2.45304E+01        85.59
    29     6.23047E-01    -8.60129E+01    -2.10317E+01     8.85469E+01      -166.26
    30     6.44531E-01    -7.32520E+01    -2.40619E+00     7.32915E+01      -178.12
    31     6.66016E-01     1.26960E+00     1.80013E+01     1.80460E+01        85.97

    32     6.87500E-01    -1.60826E+00     3.53621E+01     3.53986E+01        92.60
    33     7.08984E-01     3.50477E+01     9.28483E+00     3.62567E+01        14.84
    34     7.30469E-01    -2.55979E+01    -1.38642E+01     2.91113E+01      -151.56
    35     7.51953E-01    -3.06648E+01     2.86086E+00     3.07979E+01       174.67
    36     7.73438E-01     2.54924E+01     1.95338E+01     3.21159E+01        37.46
    37     7.94922E-01     5.14659E+00    -1.15460E+01     1.26411E+01       -65.98
    38     8.16406E-01    -1.84656E+01    -3.93144E+01     4.34350E+01    [illegible]
    39     8.37891E-01    -9.91772E-01     6.17941E+00     6.25850E+00    [illegible]
```

TABLE XI (Cont'd)

| | | | | | |
|---|---|---|---|---|---|
| 40 | [illegible] | -6.29821E+00 | -1.49896E+01 | [illegible] | [illegible] |
| 41 | [illegible] | -1.67293E+01 | -1.03988E+01 | 1.96978E+01 | -148.14 |
| 42 | 9.02344E-01 | 1.03300E+01 | -3.48111E+01 | 3.63115E+01 | -73.47 |
| 43 | 9.23828E-01 | 1.61600E+01 | -5.52346E+00 | 1.70779E+01 | -18.87 |
| 44 | 9.45313E-01 | 7.32488E+00 | -1.76196E+01 | 1.90815E+01 | -67.43 |
| 45 | 9.66797E-01 | -1.39707E+01 | -1.11046E+01 | 1.78464E+01 | -141.52 |
| 46 | 9.88281E-01 | -3.08244E+00 | -2.65203E+01 | 2.66988E+01 | -96.63 |
| 47 | 1.00977E+00 | 2.06500E+01 | 6.85130E+00 | 2.17569E+01 | 18.35 |
| | | | | | |
| 48 | 1.03125E+00 | -2.34850E+01 | -4.70353E+00 | 2.39513E+01 | -168.67 |
| 49 | 1.05273E+00 | 8.66073E+00 | -7.61692E+00 | 1.15337E+01 | -41.33 |
| 50 | [illegible] | 1.42002E+01 | 1.73075E+01 | 2.23873E+01 | [illegible] |
| 51 | [illegible] | -7.46781E+00 | 4.24216E-02 | [illegible] | [illegible] |
| 52 | [illegible] | -1.70300E+01 | -1.72601E+01 | [illegible] | [illegible] |
| 53 | 1.13667E+00 | 8.79392E+00 | 4.96266E+00 | 1.00976E+01 | 29.44 |
| 54 | 1.16016E+00 | -1.14088E+01 | 1.14676E+00 | 1.14663E+01 | 174.26 |
| 55 | 1.18164E+00 | 1.48824E+01 | -1.85699E+01 | 2.37976E+01 | -51.29 |
| | | | | | |
| 56 | 1.20313E+00 | -3.58370E+00 | -5.06927E+00 | 6.20809E+00 | -125.26 |
| 57 | 1.22461E+00 | 7.79754E+00 | 1.33918E+01 | 1.54965E+01 | 59.79 |
| 58 | 1.24609E+00 | -6.40978E+00 | 1.30449E+01 | 1.45346E+01 | 116.17 |
| 59 | 1.26758E+00 | 4.33124E+00 | 1.56318E+00 | 4.60469E+00 | 19.84 |
| 60 | 1.28906E+00 | -1.41814E+01 | -1.41744E+01 | 2.00506E+01 | -135.01 |
| 61 | 1.31055E+00 | -3.95962E+00 | 2.13084E+01 | 2.16731E+01 | 100.53 |
| 62 | 1.33203E+00 | 1.19198E+01 | 1.70024E+01 | 2.07645E+01 | 54.97 |
| 63 | 1.35352E+00 | 1.12123E+01 | -4.41696E+00 | 1.20509E+01 | -21.50 |
| | | | | | |
| 64 | 1.37500E+00 | -1.56250E+00 | 1.76563E+01 | 1.77253E+01 | 95.06 |
| 65 | 1.39648E+00 | 1.11276E+00 | 1.86572E+00 | 2.17236E+00 | 59.19 |
| 66 | 1.41797E+00 | -9.10732E+00 | 4.87213E+00 | 1.03286E+01 | 151.85 |
| 67 | 1.43945E+00 | -1.00859E+01 | -1.11911E+01 | 1.50654E+01 | -132.03 |
| 68 | 1.46094E+00 | 1.14018E+01 | -6.32041E+00 | 1.30365E+01 | -29.00 |
| 69 | 1.48242E+00 | -7.39801E+00 | 5.73904E+00 | 9.36307E+00 | 142.20 |
| 70 | 1.50391E+00 | -1.32563E+01 | 5.39112E+00 | 1.43106E+01 | 157.87 |
| 71 | 1.52539E+00 | 2.91244E+01 | -1.45681E+01 | 3.25647E+01 | -26.57 |
| | | | | | |
| 72 | 1.54688E+00 | -3.42577E+00 | -9.08342E+00 | 9.70795E+00 | -110.66 |
| 73 | 1.56836E+00 | -8.33438E+00 | -7.19591E+00 | 1.10110E+01 | -139.19 |
| 74 | 1.58984E+00 | -1.58761E+00 | -8.98015E+00 | 9.11941E+00 | -100.03 |
| 75 | 1.61133E+00 | 1.32531E+00 | 6.09348E+00 | 6.23594E+00 | 77.73 |
| 76 | 1.63281E+00 | -1.02109E+01 | 1.40944E+01 | 1.74045E+01 | 125.92 |
| 77 | 1.65430E+00 | -4.90033E+00 | 1.03016E+00 | 5.00744E+00 | 168.13 |
| 78 | 1.67578E+00 | -9.68568E+00 | 6.38179E+00 | 1.15991E+01 | 146.62 |
| 79 | 1.69727E+00 | -3.55642E+00 | -5.62833E+00 | 6.65779E+00 | -122.29 |
| | | | | | |
| 80 | 1.71875E+00 | -5.86355E+00 | 1.08705E+01 | 1.23511E+01 | 118.34 |
| 81 | 1.74023E+00 | 3.60779E+00 | -4.30412E-01 | 3.63338E+00 | -6.80 |
| 82 | 1.76172E+00 | -2.93561E+00 | 1.91805E+00 | 3.50666E+00 | 146.84 |
| 83 | 1.78320E+00 | 4.44884E+00 | 1.00820E+00 | 4.56165E+00 | 12.77 |
| 84 | 1.80469E+00 | 2.43905E+00 | -3.94084E+00 | 4.63457E+00 | -58.25 |
| 85 | 1.82617E+00 | 8.13459E+00 | 2.99127E+00 | 8.71408E+00 | 20.08 |
| 86 | [illegible] | -3.49144E+00 | 2.47859E+00 | 4.28177E+00 | [illegible] |
| 87 | [illegible] | -2.28378E+00 | 1.37707E-01 | 2.28792E+00 | [illegible] |

# TABLE XI (Cont'd)

| | | | | | |
|---|---|---|---|---|---|
| [illegible] | [illegible]3E+00 | [illegible] | [illegible]0 | 7.8[illegible] | [illegible] |
| 89 | 1.91211E+00 | [illegible] | 2.59[illegible]E+00 | 3.88519E+00 | -138.09 |
| 90 | 1.93359E+00 | 6.46264E+00 | 1.28266E+00 | 6.58870E+00 | 11.23 |
| 91 | 1.95508E+00 | -4.13891E+00 | 2.32846E+00 | 4.74893E+00 | 150.64 |
| 92 | 1.97656E+00 | 2.38828E+00 | -1.52256E+00 | 2.83232E+00 | -32.52 |
| 93 | 1.99805E+00 | 5.73805E-01 | -2.83475E+00 | 2.89224E+00 | -78.56 |
| 94 | 2.01953E+00 | 6.30298E+00 | -1.00312E+00 | 6.38231E+00 | -9.04 |
| 95 | 2.04102E+00 | -1.96648E+00 | -8.57702E+00 | 8.79957E+00 | -102.91 |
| 96 | 2.06250E+00 | -1.82924E+00 | -9.95043E+00 | 1.01172E+01 | -100.42 |
| 97 | 2.08398E+00 | 4.43762E+00 | 5.45395E+00 | 7.03122E+00 | 50.87 |
| 98 | 2.10547E+00 | 6.04288E+00 | -7.39588E+00 | 9.55068E+00 | -50.75 |
| 99 | 2.12695E+00 | -2.46920E+00 | -4.37724E-01 | 2.50770E+00 | -169.95 |
| 100 | 2.14844E+00 | 4.46415E+00 | 7.18980E+00 | 8.46297E+00 | 58.16 |
| 101 | 2.16992E+00 | -2.06360E+00 | -1.27429E+00 | 2.42534E+00 | -148.30 |
| 102 | 2.19141E+00 | -3.52992E-01 | -3.59263E+00 | 3.60993E+00 | -95.61 |
| 103 | 2.21289E+00 | -3.43973E+00 | 1.72214E+00 | 3.84675E+00 | 153.40 |
| 104 | 2.23438E+00 | 2.61648E+00 | 2.62099E+00 | 3.70345E+00 | 45.05 |
| 105 | 2.25586E+00 | -9.37128E+00 | -1.72932E+00 | 9.52951E+00 | -169.54 |
| 106 | 2.27734E+00 | -1.41818E+00 | 3.80544E-01 | 1.46835E+00 | 164.98 |
| 107 | 2.29883E+00 | -1.16358E+00 | -4.66612E+00 | 4.80901E+00 | -104.00 |
| 108 | 2.32031E+00 | 9.90368E+00 | 7.20514E-02 | 9.90394E+00 | .42 |
| 109 | 2.34180E+00 | -3.58951E+00 | -2.74263E+00 | 4.517[illegible] | -1[illegible] |
| 110 | 2.36328E+00 | 9.12973E+00 | 2.51070E+00 | 9.468[illegible] | 1[illegible] |
| 111 | 2.38477E+00 | 2.98918E+00 | -1.99324E+00 | 3.59279E+00 | -33.70 |
| 112 | 2.40625E+00 | 5.59410E+00 | -7.07516E+00 | 9.01952E+00 | -51.67 |
| 113 | 2.42773E+00 | 2.13953E+00 | 1.80685E+00 | 2.80042E+00 | 40.18 |
| 114 | 2.44922E+00 | 1.17494E+01 | 9.78102E+00 | 1.52878E+01 | 39.78 |
| 115 | 2.47070E+00 | -9.03355E+00 | -5.61874E+00 | 1.06384E+01 | -148.12 |
| 116 | 2.49219E+00 | -2.74846E+00 | 7.99086E-01 | 2.86226E+00 | 163.79 |
| 117 | 2.51367E+00 | 1.51662E+00 | 3.93849E+00 | 4.22041E+00 | 68.94 |
| 118 | 2.53516E+00 | 1.67147E+00 | 3.14376E-01 | 1.70078E+00 | 10.65 |
| 119 | 2.55664E+00 | 1.23170E+00 | -7.15676E-01 | 1.42452E+00 | -30.16 |
| 120 | 2.57813E+00 | 5.56595E-01 | 3.47623E+00 | 3.52051E+00 | 80.90 |
| 121 | 2.59961E+00 | -3.73711E+00 | -2.00612E+00 | 4.24152E+00 | -151.77 |
| 122 | 2.62109E+00 | 2.60609E-01 | -8.31441E+00 | 8.31849E+00 | -88.20 |
| 123 | 2.64258E+00 | 3.68183E+00 | -1.81169E+00 | 4.10342E+00 | -26.20 |
| 124 | 2.66406E+00 | 2.70677E+00 | 1.82509E+00 | 3.26459E+00 | 33.99 |
| 125 | 2.68555E+00 | -3.81240E-01 | 3.62664E-01 | 5.26183E-01 | 136.43 |
| 126 | 2.70703E+00 | -5.18660E+00 | -5.73912E+00 | 7.73552E+00 | -132.10 |
| 127 | 2.72852E+00 | 5.60483E+00 | -4.03566E+00 | 6.9065[illegible]E+00 | -[illegible] |

# TABLE XII

## POWER

| COEFF. | FREQ.[Hz] | POWER | ( )/MAX |
|---|---|---|---|
| DC | 0.00000E+00 | 0.00000E+00 | 0.000 |
| MAX | 2.75000E+00 | 2.69165E+00 | .000 |
| 1 | 2.14844E-02 | 1.44252E+03 | .121 |
| 2 | 4.29688E-02 | 1.71332E+03 | .144 |
| 3 | 6.44531E-02 | 2.55038E+03 | .214 |
| 4 | 8.59375E-02 | 1.14852E+04 | .965 |
| 5 | 1.07422E-01 | 1.19002E+04 | 1.000 |
| 6 | 1.28906E-01 | 3.92235E+02 | .033 |
| 7 | 1.50391E-01 | 2.47003E+03 | .208 |
| 8 | 1.71875E-01 | 4.91880E+03 | .413 |
| 9 | 1.93359E-01 | 2.34205E+03 | .197 |
| 10 | 2.14844E-01 | 3.00508E+03 | .253 |
| 11 | 2.36328E-01 | 2.36460E+03 | .199 |
| 12 | 2.57813E-01 | 1.67072E+03 | .140 |
| 13 | 2.79297E-01 | 4.51030E+02 | .038 |
| 14 | 3.00781E-01 | 3.49006E+00 | .000 |
| 15 | 3.22266E-01 | 6.39012E+03 | .537 |
| 16 | 3.43750E-01 | 2.26831E+03 | .191 |
| 17 | 3.65234E-01 | 2.32068E+03 | .195 |
| 18 | 3.86719E-01 | 6.95151E+03 | .584 |
| 19 | 4.08203E-01 | 1.67816E+03 | .141 |
| 20 | 4.29688E-01 | 1.51551E+03 | .127 |
| 21 | 4.51172E-01 | 8.51241E+02 | .072 |
| 22 | 4.72656E-01 | 1.28808E+03 | .108 |
| 23 | 4.94141E-01 | 9.12759E+02 | .077 |
| 24 | 5.15625E-01 | 1.49953E+03 | .126 |
| 25 | 5.37109E-01 | 2.22998E+03 | .187 |
| 26 | 5.58594E-01 | 5.85507E+02 | .049 |
| 27 | 5.80078E-01 | 7.34971E+02 | .062 |
| 28 | 6.01563E-01 | 6.01739E+02 | .051 |
| 29 | 6.23047E-01 | 7.84055E+03 | .659 |
| 30 | 6.44531E-01 | 5.37164E+03 | .451 |
| 31 | 6.66016E-01 | 3.25658E+02 | .027 |
| 32 | 6.87500E-01 | 1.25306E+03 | .105 |
| 33 | 7.08984E-01 | 1.31455E+03 | .110 |
| 34 | 7.30469E-01 | 8.47470E+02 | .071 |
| 35 | 7.51953E-01 | 9.48512E+02 | .080 |
| 36 | 7.73438E-01 | 1.03143E+03 | .087 |
| 37 | 7.94922E-01 | 1.59798E+02 | .013 |
| 38 | 8.16406E-01 | 1.88660E+03 | .159 |
| 39 | 8.37891E-01 | 3.91688E+01 | .003 |

TABLE XII (Cont'd)

| | | | |
|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | .033 |
| 42 | 9.02344E-01 | 1.31853E+03 | .111 |
| 43 | 9.23828E-01 | 2.91655E+02 | .025 |
| 44 | 9.45313E-01 | 3.64104E+02 | .031 |
| 45 | 9.66797E-01 | 3.18494E+02 | .027 |
| 46 | 9.88281E-01 | 7.12825E+02 | .060 |
| 47 | 1.00977E+00 | 4.73365E+02 | .040 |
| 48 | 1.03125E+00 | 5.73667E+02 | .048 |
| 49 | 1.05273E+00 | 1.33026E+02 | .011 |
| 50 | 1.07422E+00 | 5.01193E+02 | .042 |
| 51 | 1.09570E+00 | 5.57699E+01 | .005 |
| 52 | 1.11719E+00 | 5.87934E+02 | .049 |
| 53 | 1.13867E+00 | 1.01961E+02 | .009 |
| 54 | 1.16016E+00 | 1.31476E+02 | .011 |
| 55 | 1.18164E+00 | 5.66326E+02 | .048 |
| 56 | 1.20313E+00 | 3.85404E+01 | .003 |
| 57 | 1.22461E+00 | 2.40141E+02 | .020 |
| 58 | 1.24609E+00 | 2.11255E+02 | .018 |
| 59 | 1.26758E+00 | 2.12031E+01 | .002 |
| 60 | 1.28906E+00 | 4.02025E+02 | .034 |
| 61 | 1.31055E+00 | 4.69725E+02 | .039 |
| 62 | 1.33203E+00 | 4.31164E+02 | .036 |
| 63 | 1.35352E+00 | 1.45225E+02 | .012 |
| 64 | 1.37500E+00 | 3.14185E+02 | .026 |
| 65 | 1.39648E+00 | 4.71914E+00 | .000 |
| 66 | 1.41797E+00 | 1.06681E+02 | .009 |
| 67 | 1.43945E+00 | 2.26967E+02 | .019 |
| 68 | 1.46094E+00 | 1.69949E+02 | .014 |
| 69 | 1.48242E+00 | 8.76672E+01 | .007 |
| 70 | 1.50391E+00 | 2.04793E+02 | .017 |
| 71 | 1.52539E+00 | 1.06046E+03 | .089 |
| 72 | 1.54688E+00 | 9.42443E+01 | .008 |
| 73 | 1.56836E+00 | 1.21243E+02 | .010 |
| 74 | 1.58984E+00 | 8.31636E+01 | .007 |
| 75 | 1.61133E+00 | 3.88870E+01 | .003 |
| 76 | 1.63281E+00 | 3.02916E+02 | .025 |
| 77 | 1.65430E+00 | 2.50745E+01 | .002 |
| 78 | 1.67578E+00 | 1.34540E+02 | .011 |
| 79 | 1.69727E+00 | 4.43262E+01 | .004 |
| 80 | 1.71875E+00 | 1.52550E+02 | .013 |
| 81 | 1.74023E+00 | 1.32014E+01 | .001 |
| 82 | 1.76172E+00 | 1.22967E+01 | .001 |
| 83 | 1.78320E+00 | 2.08087E+01 | .002 |
| 84 | 1.80469E+00 | 2.14792E+01 | .002 |
| 85 | 1.82617E+00 | 7.59352E+01 | .006 |
| 86 | 1.84766E+00 | 1.83335E+01 | .002 |
| 87 | 1.86914E+00 | 5.23460E+00 | .000 |

# TABLE XII (Cont'd)

| | | | |
|---|---|---|---|
| [illegible] | 1.89063E+00 | 6.21307E+01 | .005 |
| 89 | 1.91211E+00 | 1.50947E+01 | .001 |
| 90 | 1.93359E+00 | 4.34109E+01 | .004 |
| 91 | 1.95508E+00 | 2.25523E+01 | .002 |
| 92 | 1.97656E+00 | 8.02206E+00 | .001 |
| 93 | 1.99805E+00 | 8.36504E+00 | .001 |
| 94 | 2.01953E+00 | 4.07339E+01 | .003 |
| 95 | 2.04102E+00 | 7.74324E+01 | .007 |
| 96 | 2.06250E+00 | 1.02357E+02 | .009 |
| 97 | 2.08398E+00 | 4.94381E+01 | .004 |
| 98 | 2.10547E+00 | 9.12155E+01 | .008 |
| 99 | 2.12695E+00 | 6.28853E+00 | .001 |
| 100 | 2.14844E+00 | 7.16219E+01 | .006 |
| 101 | 2.16992E+00 | 5.88227E+00 | .000 |
| 102 | 2.19141E+00 | 1.30316E+01 | .001 |
| 103 | 2.21289E+00 | 1.47975E+01 | .001 |
| 104 | 2.23438E+00 | 1.37156E+01 | .001 |
| 105 | 2.25586E+00 | 9.08115E+01 | .008 |
| 106 | 2.27734E+00 | 2.15606E+00 | .000 |
| 107 | 2.29883E+00 | 2.31266E+01 | .002 |
| 108 | 2.32031E+00 | 9.80881E+01 | .008 |
| 109 | 2.34180E+00 | 2.04066E+01 | .002 |
| 110 | 2.36328E+00 | 8.96555E+01 | [illegible] |
| 111 | 2.38477E+00 | 1.29082E+01 | .001 |
| 112 | 2.40625E+00 | 8.13518E+01 | .007 |
| 113 | 2.42773E+00 | 7.84233E+00 | .001 |
| 114 | 2.44922E+00 | 2.33717E+02 | .020 |
| 115 | 2.47070E+00 | 1.13175E+02 | .010 |
| 116 | 2.49219E+00 | 8.19256E+00 | .001 |
| 117 | 2.51367E+00 | 1.78119E+01 | .001 |
| 118 | 2.53516E+00 | 2.89265E+00 | .000 |
| 119 | 2.55664E+00 | 2.02927E+00 | .000 |
| 120 | 2.57813E+00 | 1.23940E+01 | .001 |
| 121 | 2.59961E+00 | 1.79905E+01 | .002 |
| 122 | 2.62109E+00 | 6.91973E+01 | .006 |
| 123 | 2.64258E+00 | 1.68381E+01 | .001 |
| 124 | 2.66406E+00 | 1.06576E+01 | .001 |
| 125 | 2.68555E+00 | 2.76869E-01 | .000 |
| 126 | 2.70703E+00 | 5.98383E+01 | .005 |
| 127 | 2.72852E+00 | 4.77007E+01 | .004 |

# TABLE XIII

| frequency | $Y_1 * Y_2$ (note 1) |
|---|---|
| 0214844 | 170816.0058 |
| 0429688 | 419365.90976 |
| 0644531 | 87908.283106 |
| .0859375 | 1046081.20416 |
| .107422 | 6997900.7098 |
| .128906 | 355270.381365 |
| .150391 | 300444.56908 |
| .171875 | 540399.0432 |
| .193359 | 87983.558145 |
| .214844 | 1836254.134 |
| .236328 | 305844.4578 |
| .257813 | 130598.51168 |
| .279297 | 36744.015907 |
| .300781 | 1024.98525122 |
| .322266 | 338338.961664 |
| .34375 | 255985.58843 |
| .365234 | 421867.13448 |
| .386719 | 807702.89841 |
| .408203 | 27082.313896 |
| .429688 | 35980.480665 |
| .451172 | 27949.3064976 |
| .472656 | 86715.47772 |
| .494141 | 41870.1721239 |
| .515625 | 57780.489772 |
| .537109 | 238636.84974 |
| .558594 | 13872.5930031 |
| .580078 | 36333.6588705 |
| .601563 | 29025.6629257 |
| .623047 | 102315.257225 |
| .644531 | 194832.605784 |
| .666016 | 7161.6102096 |
| .6875 | 58221.302698 |
| .708984 | 32756.614175 |
| .730469 | 34932.204918 |
| .751953 | 3771.41650368 |
| .773438 | 99150.953328 |
| .794922 | 737.41503666 |
| .816406 | 3203.390202 |
| .837891 | 216.88352092 |
| .859375 | 5909.1537505 |

note 1: $Y_1 * Y_2$ = magnitude of 15000 rpm in the power spectrum times magnitude of 19000 rpm in the power spectrum

## TABLE XIV

| frequency | referred magnitude (note 1) |
|---|---|
| .0214844 | 2.44096069498E-02 |
| .0429688 | 5.99273878197E-02 |
| .0644531 | 1.25620935123E-02 |
| .0859375 | .149485002366 |
| .107422 | 1 |
| .128906 | 5.07681369168E-02 |
| .150391 | 4.29335284308E-02 |
| .171875 | 7.72230223906E-02 |
| .193359 | 1.25728503152E-02 |
| .214844 | .262400712749 |
| .236328 | 4.37051725201E-02 |
| .257813 | 1.86625271058E-02 |
| .279297 | 5.25071981309E-03 |
| .300781 | 1.46470390725E-04 |
| .322266 | 4.83486370691E-02 |
| .34375 | 3.65303401685E-02 |
| .365234 | 6.02348128281E-02 |
| .386719 | .115420742863 |
| .408203 | 3.87006261150E-03 |
| .429688 | 5.14161062826E-03 |
| .451172 | 3.99395585285E-03 |
| .472656 | 1.23916416245E-02 |
| .494141 | 5.98324752811E-03 |
| .515625 | 8.25683189404E-03 |
| .537109 | 3.41012054381E-02 |
| .558594 | 1.98239351748E-03 |
| .580078 | 5.19207979325E-03 |
| .601563 | 4.14776718467E-03 |
| .623047 | 1.46208500903E-02 |
| .644531 | 2.78415790483E-02 |
| .666016 | 1.02339408725E-03 |
| .6875 | 8.31982406045E-03 |
| .708984 | 4.68092011210E-03 |
| .730469 | 4.99181202572E-03 |
| .751953 | 5.38935412216E-04 |
| .773438 | 1.41686710686E-02 |
| .794922 | 1.05376607534E-04 |
| .816406 | 4.57764454633E-04 |
| .837891 | 3.09926547852E-05 |
| .859375 | 8.44418061294E-04 |

note 1: each $Y_1*Y_2$ value in Table XIII has been referred by division by the largest value computed. The largest value occurs at a frequency of .107422 HZ.

## TABLE XV

## DEFINITION OF COLUMN HEADINGS IN TABLES XVI TO XXXVII

| SYMBOL | DEFINITION |
|---|---|
| C-DELT | Stage $\Delta T$ calculated from the measured HP. |
| DIFF | (DEL T) - (C-DELT) |
| V1 | Velocity at Stator Exit Plane (ft/sec) |
| V2 | Velocity at Rotor Exit Plane (ft/sec) |
| VA1 | Axial Velocity at Stator Exit Plane (ft/sec) |
| VA2 | Axial Velocity at Rotor Exit Plane (ft/sec) |
| VU1 | Tangential Velocity at Stator Exit Plane (ft/sec) |
| VU2 | Tangential Velocity at Rotor Exit Plane (ft/sec) |
| M1 | Mach Number at Stator Exit Plane |
| MA1 | Axial Mach Number at Stator Exit Plane |
| M2 | Mach Number at Rotor Exit Plane |
| MA2 | Axial Mach Number at Rotor Exit Plane |
| A1 | Flow Angle at Stator Exit Plane (degrees) |
| A2 | Flow Angle at Rotor Exit Plane (degrees) |
| B1 | Relative Flow Angle at Rotor Inlet Plane (degrees) |
| B2 | Relative Flow Angle at Rotor Exit Plane (degrees) |

TABLE XV (Cont'd)

| SYMBOL | DEFINITION |
|---|---|
| ZS or Z1 | Stator Loss Coefficient |
| ZSTH | Theoretical Stator Loss Coefficient |
| ZR or Z3 | Rotor Loss Coefficient |
| ZRTH | Theoretical Rotor Loss Coefficient |
| ZR* | Rotor Carry Over Loss Coefficient |
| ZI | Rotor Incidence Loss Coefficient |
| Y | After Expansion Loss Coefficient |
| P.R. | Pressure Ratio $P_{t_o}/P_2$ |
| STPR | Stator Pressure Ratio |
| H.P. | Horsepower |
| RTM or DYNA Q | Rotor Torque (Moment) (in-lbf) |
| STM or STATOR Q | Stator Torque (Moment) (in-lbf) |
| AXF or AX FORCE | Stator Axial Force - Force Capsule (lbf) |
| CLF or CL FORCE | Closure Plate Force - Force Capsule (lbf) |
| MW-DOT | Computed Mass Flow Rate (lbm/sec) |
| PTO | Total Pressure (in Hg) |
| TTO | Total Temperature (°R) |
| PHD | Hood Pressure (in Hg) |
| P-TIP | Static Pressure at Stator Tap Tip #3 (in Hg) |
| P1 | Computed Stator Exit Pressure (in Hg) |
| P-HUB | Static Pressure at Stator Tap "HUB #3" (in Hg) |
| P-TIP/PTO | Pressure Ratio of $P_{tip}/P_{t_o}$ |

| SYMBOL | DEFINITION |
|---|---|
| P1/PTO | Pressure Ratio of $P_1/P_{t_o}$ |
| P-HUB/PTO | Pressure Ratio of $P_{hub}/P_{t_o}$ |
| KIS | Isentropic Head Coefficient |
| TURB RE | Reynold's Number at the Stator Entrance |
| DELT or DEL T | Temperature Difference Across the Stage = $T_{t_o} - T_{hood}$ |
| ETA | Total to Static Efficiency |
| DELTA | Pressure Ratio, $\delta = \frac{P_{t_o}}{P_{ref}}$ ($P_{ref}$=29.92) |
| THETA | Temperature Ratio, $\theta = \frac{T_{t_o}}{T_{ref}}$ ($T_{ref}$ = 518.7°R) |
| RHP | Referred Horsepower |
| RMW-DOT | Referred Computed Mass Flow Rate (lbm/sec) |
| RRTM | Referred Rotor Torque (Moment) (in-lbf) |
| RSTM | Referred Stator Torque (Moment) (in-lbf) |
| RN | Referred RPM (RPM) |
| RTH | Theoretical Degree of Reaction |
| REFF | Effective Degree of Reaction |
| RAF | Resultant Axial Force (computed) (lbf) |
| RPM | Rotor Speed (RPM) |
| P1<br>P2<br>P3<br>P4<br>P5<br>P6<br>P7<br>P8<br>P9 | Pressure Ratios Corresponding to Tap Locations in Figure 6. Pressures are referred to Stator Inlet Total Pressure ($P_{t_o}$) |

## TABLE XVI

## TEMPERATURE DROP CALCULATED FROM THE MEASURED POWER AND MEASURED VALUES

### RUN 10

| PT. | H.P. | R-H.P. | RMW-DOT | TTO | DEL T | C-DEL T | DIFF |
|---|---|---|---|---|---|---|---|
| 1 | 78.54 | 35.58 | 1.02664 | 636.4 | 119.6 | 125.2 | -5.7 |
| 2 | 83.39 | 37.62 | 1.02503 | 635.9 | 130.7 | 132.5 | -1.8 |
| 3 | 87.64 | 39.75 | 1.02766 | 636.0 | 136.9 | 139.7 | -2.8 |
| 4 | 90.08 | 40.69 | 1.02446 | 635.5 | 140.5 | 143.3 | -2.8 |
| 5 | 92.44 | 41.82 | 1.02408 | 634.6 | 142.2 | 147.1 | -4.9 |
| 6 | 94.85 | 42.92 | 1.02434 | 634.6 | 145.4 | 150.9 | -5.6 |
| 7 | 96.83 | 43.84 | 1.02544 | 634.2 | 148.9 | 153.9 | -5.0 |
| 8 | 98.35 | 44.53 | 1.02482 | 634.2 | 146.5 | 156.4 | -10.0 |
| 9 | 102.53 | 45.69 | 1.02482 | 634.4 | 151.3 | 160.6 | -9.3 |

### RUN 11

| PT. | H.P. | R-H.P. | RMW-DOT | TTO | DEL T | C-DEL T | DIFF |
|---|---|---|---|---|---|---|---|
| 1 | 98.62 | 35.58 | 1.02707 | 641.0 | 121.6 | 126.1 | -4.4 |
| 2 | 104.40 | 37.49 | 1.02358 | 641.0 | 129.7 | 133.3 | -3.6 |
| 3 | 107.81 | 39.14 | 1.02576 | 640.6 | 136.8 | 138.8 | -2.0 |
| 4 | 112.28 | 40.60 | 1.02602 | 639.6 | 139.9 | 143.7 | -3.8 |
| 5 | 115.51 | 41.57 | 1.02445 | 639.1 | 141.1 | 147.2 | -6.2 |
| 6 | 117.92 | 42.63 | 1.02499 | 639.0 | 142.4 | 150.9 | -8.5 |
| 7 | 119.70 | 43.26 | 1.02536 | 638.6 | 148.1 | 153.0 | -4.9 |
| 8 | 121.83 | 44.02 | 1.02712 | 638.6 | 146.3 | 155.4 | -9.1 |

### RUN 12

| PT. | H.P. | R-H.P. | RMW-DOT | TTO | DEL T | C-DEL T | DIFF |
|---|---|---|---|---|---|---|---|
| 1 | 81.85 | 38.87 | 1.01757 | 574.1 | 97.8 | 124.5 | -26.7 |
| 2 | 85.83 | 40.95 | 1.01772 | 572.5 | 101.5 | 130.8 | -29.3 |
| 3 | 90.24 | 42.95 | 1.01778 | 571.9 | 103.2 | 137.0 | -33.8 |
| 4 | 89.68 | 42.68 | 1.01646 | 571.5 | 104.1 | 136.3 | -32.1 |
| 5 | 88.08 | 41.97 | 1.01765 | 571.3 | 106.2 | 133.8 | -27.6 |
| 6 | 93.34 | 44.57 | 1.01758 | 570.9 | 107.7 | 142.0 | -34.3 |

## RUN 13

| PT. | H.P. | R-H.P. | RMW-DOT | TTO | DEL T | C-DEL T | DIFF |
|---|---|---|---|---|---|---|---|
| 1 | 79.95 | 37.75 | 1.01942 | 574.3 | 90.5 | 120.8 | -30.3 |
| 2 | 84.17 | 39.94 | 1.02128 | 572.8 | 99.9 | 127.2 | -27.3 |
| 3 | 87.13 | 41.30 | 1.02258 | 572.9 | 96.6 | 131.4 | -34.8 |
| 4 | 88.76 | 42.17 | 1.02399 | 573.1 | 96.2 | 134.0 | -37.8 |
| 5 | 89.69 | 42.65 | 1.02403 | 573.3 | 97.3 | 135.6 | -38.3 |
| 6 | 91.25 | 43.31 | 1.02368 | 573.4 | 96.7 | 137.7 | -41.0 |
| 7 | 92.76 | 43.95 | 1.02320 | 574.2 | 96.3 | 140.0 | -43.8 |
| 8 | 91.87 | 43.51 | 1.02239 | 574.5 | 98.7 | 138.8 | -40.1 |

## RUN 14

| PT. | H.P. | R-H.P. | RMW-DOT | TTO | DEL T | C-DEL T | DIFF |
|---|---|---|---|---|---|---|---|
| 1 | 79.91 | 37.16 | 1.02273 | 603.1 | 117.5 | 124.4 | -6.9 |
| 2 | 85.42 | 39.45 | 1.02051 | 602.2 | 120.2 | 132.2 | -11.9 |
| 3 | 87.89 | 40.67 | 1.02228 | 602.2 | 121.0 | 136.0 | -15.0 |
| 4 | 89.39 | 41.38 | 1.02081 | 602.0 | 123.4 | 138.5 | -15.1 |
| 5 | 92.64 | 42.74 | 1.02100 | 602.0 | 124.6 | 143.1 | -18.4 |
| 6 | 92.69 | 43.02 | 1.02172 | 602.0 | 123.3 | 143.9 | -20.6 |
| 7 | 93.35 | 43.20 | 1.02208 | 602.5 | 123.8 | 144.6 | -20.8 |
| 8 | 94.63 | 43.74 | 1.02258 | 602.5 | 121.6 | 146.3 | -24.8 |

## RUN 15

| PT. | H.P. | R-H.P. | RMW-DOT | TTO | DEL T | C-DEL T | DIFF |
|---|---|---|---|---|---|---|---|
| 1 | 84.34 | 36.92 | 1.02403 | 670.5 | 136.5 | 137.3 | -0.8 |
| 2 | 87.97 | 38.49 | 1.02587 | 673.0 | 143.2 | 143.4 | -0.2 |
| 3 | 91.40 | 40.02 | 1.02753 | 674.3 | 149.3 | 149.1 | 0.2 |
| 4 | 94.05 | 41.17 | 1.02811 | 675.3 | 152.0 | 153.5 | -1.6 |
| 5 | 98.24 | 42.82 | 1.02575 | 676.3 | 154.9 | 160.3 | -5.4 |
| 6 | 100.57 | 43.79 | 1.02652 | 676.9 | 162.2 | 164.0 | -1.8 |
| 7 | 102.66 | 44.88 | 1.02918 | 677.2 | 162.4 | 167.7 | -5.2 |
| 8 | 102.72 | 44.92 | 1.02994 | 677.3 | 163.0 | 167.7 | -4.7 |

# TABLE XVII

## TTR INPUT DATA

| PORT NO. | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 10 | 1 | 0.000002 | 0.001361 | 0.006318 | 0.006112 | 0.004095 | 0.004034 |
| 10 | 2 | 0.000002 | 0.001361 | 0.006361 | 0.006153 | 0.004119 | 0.004073 |
| 10 | 3 | 0.000001 | 0.001361 | 0.006317 | 0.006111 | 0.004091 | 0.004032 |
| 10 | 4 | 0.000001 | 0.001361 | 0.006360 | 0.006151 | 0.004115 | 0.004070 |
| 10 | 5 | 0.000001 | 0.001360 | 0.006343 | 0.006136 | 0.004112 | 0.004065 |
| 10 | 6 | 0.000001 | 0.001360 | 0.006353 | 0.006144 | 0.004109 | 0.004063 |
| 10 | 7 | 0.000000 | 0.001360 | 0.006350 | 0.006140 | 0.004108 | 0.004058 |
| 10 | 8 | 0.000001 | 0.001360 | 0.006346 | 0.006139 | 0.004107 | 0.004061 |
| 10 | 9 | 0.000001 | 0.001360 | 0.006517 | 0.006304 | 0.004233 | 0.004189 |

| PORT NO. | | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 10 | 1 | 0.004039 | 0.003980 | 0.004039 | 0.004028 | -0.001739 | -0.002431 |
| 10 | 2 | 0.004078 | 0.004015 | 0.004079 | 0.004068 | -0.001756 | -0.002372 |
| 10 | 3 | 0.004037 | 0.003978 | 0.004039 | 0.004029 | -0.001748 | -0.002305 |
| 10 | 4 | 0.004075 | 0.004014 | 0.004077 | 0.004065 | -0.001762 | -0.002244 |
| 10 | 5 | 0.004069 | 0.004007 | 0.004069 | 0.004058 | -0.001761 | -0.002186 |
| 10 | 6 | 0.004069 | 0.004007 | 0.004069 | 0.004058 | -0.001762 | -0.002119 |
| 10 | 7 | 0.004064 | 0.004005 | 0.004064 | 0.004052 | -0.001764 | -0.002035 |
| 10 | 8 | 0.004067 | 0.004004 | 0.004066 | 0.004054 | -0.001763 | -0.001995 |
| 10 | 9 | 0.004196 | 0.004134 | 0.004196 | 0.004185 | -0.001805 | -0.001791 |

| PORT NO. | | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 10 | 1 | -0.000506 | -0.002046 | -0.001789 | -0.002358 | -0.002486 | 0.001275 |
| 10 | 2 | -0.000491 | -0.002036 | -0.001778 | -0.002263 | -0.002436 | 0.001299 |
| 10 | 3 | -0.000505 | -0.002044 | -0.001787 | -0.002109 | -0.002380 | 0.001274 |
| 10 | 4 | -0.000491 | -0.002037 | -0.001777 | -0.001944 | -0.002329 | 0.001303 |
| 10 | 5 | -0.000494 | -0.002038 | -0.001777 | -0.001769 | -0.002279 | 0.001302 |
| 10 | 6 | -0.000492 | -0.002038 | -0.001775 | -0.001534 | -0.002212 | 0.001304 |
| 10 | 7 | -0.000493 | -0.002039 | -0.001774 | -0.001460 | -0.002148 | 0.001305 |
| 10 | 8 | -0.000492 | -0.002038 | -0.001770 | -0.001385 | -0.002098 | 0.001309 |
| 10 | 9 | -0.000435 | -0.002006 | -0.001728 | -0.001191 | -0.001970 | 0.001401 |

| PORT NO. | | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 10 | 1 | -0.000056 | -0.002433 | -0.002438 | 0.000147 | -0.001675 | -0.001808 |
| 10 | 2 | -0.000048 | -0.002421 | -0.002382 | 0.000164 | -0.001611 | -0.001650 |
| 10 | 3 | -0.000062 | -0.002415 | -0.002311 | 0.000143 | -0.001547 | -0.001558 |
| 10 | 4 | -0.000049 | -0.002405 | -0.002253 | 0.000166 | -0.001459 | -0.001460 |
| 10 | 5 | -0.000058 | -0.002401 | -0.002185 | 0.000160 | -0.001355 | -0.001375 |
| 10 | 6 | -0.000062 | -0.002391 | -0.002119 | 0.000160 | -0.001275 | -0.001284 |
| 10 | 7 | -0.000061 | -0.002381 | -0.002046 | 0.000159 | -0.001209 | -0.001193 |
| 10 | 8 | -0.000061 | -0.002366 | -0.001997 | 0.000159 | -0.001171 | -0.001113 |
| 10 | 9 | -0.000016 | -0.002328 | -0.001777 | 0.000230 | -0.001021 | -0.000899 |

| PORT NO. | | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 10 | 1 | 0.000001 | 0.001360 | 0.004064 | -0.002432 | -0.001817 | -0.001588 |
| 10 | 2 | 0.000001 | 0.001361 | 0.004082 | -0.002378 | -0.001733 | -0.001501 |
| 10 | 3 | 0.000000 | 0.001360 | 0.004039 | -0.002306 | -0.001640 | -0.001413 |
| 10 | 4 | 0.000001 | 0.001360 | 0.004089 | -0.002246 | -0.001542 | -0.001321 |
| 10 | 5 | 0.000000 | 0.001359 | 0.004080 | -0.002182 | -0.001436 | -0.001211 |
| 10 | 6 | 0.000001 | 0.001361 | 0.004087 | -0.002113 | -0.001347 | -0.001124 |
| 10 | 7 | 0.000001 | 0.001360 | 0.004063 | -0.002042 | -0.001261 | -0.001075 |
| 10 | 8 | 0.000000 | 0.001360 | 0.004065 | -0.001972 | -0.001199 | -0.001026 |
| 10 | 9 | 0.000001 | 0.001360 | 0.004200 | -0.001786 | -0.001017 | -0.000883 |

```
PORT NO.      31         32         33         34         35         36
RUN PT.
10   1   -0.001592 -0.001480 -0.001479 -0.001550 -0.001509 -0.001401
10   2   -0.001513 -0.001415 -0.001405 -0.001477 -0.001476 -0.001415
10   3   -0.001443 -0.001362 -0.001384 -0.001455 -0.001419 -0.001381
10   4   -0.001371 -0.001313 -0.001347 -0.001465 -0.001451 -0.001374
10   5   -0.001303 -0.001312 -0.001323 -0.001434 -0.001437 -0.001366
10   6   -0.001238 -0.001229 -0.001278 -0.001432 -0.001469 -0.001401
10   7   -0.001195 -0.001182 -0.001210 -0.001374 -0.001414 -0.001387
10   8   -0.001151 -0.001136 -0.001166 -0.001345 -0.001387 -0.001370
10   9   -0.001011 -0.001031 -0.001057 -0.001253 -0.001325 -0.001348

PORT NO.      37         38         39         40         41         42
RUN PT.
10   1   -0.001706 -0.001763 -0.001730 -0.001759 -0.001744 -0.001754
10   2   -0.001750 -0.001787 -0.001736 -0.001763 -0.001771 -0.001776
10   3   -0.001733 -0.001775 -0.001738 -0.001759 -0.001758 -0.001769
10   4   -0.001736 -0.001799 -0.001766 -0.001785 -0.001785 -0.001784
10   5   -0.001722 -0.001792 -0.001763 -0.001783 -0.001792 -0.001787
10   6   -0.001719 -0.001794 -0.001753 -0.001788 -0.001795 -0.001793
10   7   -0.001729 -0.001797 -0.001741 -0.001784 -0.001793 -0.001792
10   8   -0.001733 -0.001845 -0.001735 -0.001779 -0.001785 -0.001788
10   9   -0.001783 -0.001954 -0.001804 -0.001834 -0.001834 -0.001836

PORT NO.      43         44         45         46         47         48
RUN PT.
10   1   -0.001738 -0.001732 -0.001759 -0.001760  0.000001  0.000001
10   2   -0.001761 -0.001751 -0.001767 -0.001766  0.000001  0.000001
10   3   -0.001758 -0.001748 -0.001751 -0.001750  0.000002  0.000001
10   4   -0.001778 -0.001775 -0.001770 -0.001771  0.000001  0.000000
10   5   -0.001771 -0.001772 -0.001766 -0.001766  0.000000  0.000001
10   6   -0.001778 -0.001774 -0.001771 -0.001771  0.000000  0.000000
10   7   -0.001777 -0.001774 -0.001771 -0.001769  0.000001  0.000002
10   8   -0.001771 -0.001771 -0.001766 -0.001766  0.000000  0.000000
10   9   -0.001816 -0.001817 -0.001816 -0.001816  0.000001  0.000000

CHANNEL      0          1          2          3          4          RPM
RUN PT
10   1  0.005023   0.004720   0.004269   0.003491   0.004200     11077
10   2  0.005005   0.004705   0.004253   0.003460   0.004184     12057
10   3  0.005031   0.004724   0.004246   0.003463   0.004188     13089
10   4  0.005011   0.004712   0.004228   0.003475   0.004174     14078
10   5  0.004989   0.004689   0.004198   0.003459   0.004146     15051
10   6  0.004990   0.004693   0.004197   0.003474   0.004145     16045
10   7  0.004983   0.004683   0.004195   0.003483   0.004134     16935
10   8  0.004988   0.004686   0.004196   0.003486   0.004133     18384
10   9  0.005020   0.004707   0.004203   0.003507   0.004140     19346

CHANNEL      5          6          20         21         23         RPM
RUN PT
10   1  0.000696   0.002843  -0.001219   0.000590   0.004469     11077
10   2  0.000365   0.002711  -0.001062   0.000724   0.004359     12057
10   3  0.000194   0.002701  -0.000909   0.000862   0.004220     13089
10   4  0.000080   0.002645  -0.000769   0.001025   0.004033     14078
10   5  0.000007   0.002528  -0.000633   0.001240   0.003871     15051
10   6 -0.000082   0.002755  -0.000465   0.001257   0.003726     16045
10   7 -0.000191   0.002939  -0.000292   0.001349   0.003604     16935
10   8 -0.000124   0.002974  -0.000035   0.001657   0.003372     18384
10   9 -0.000252   0.002957   0.000232   0.001873   0.003340     19346
```

```
CHANNEL     23         24         25         26         27          RPM
RUN  PT
10    1  0.004469  0.003610  0.003004  0.007686  0.002094        11077
10    2  0.004359  0.003587  0.003004  0.007711  0.002100        12057
10    3  0.004220  0.003541  0.002999  0.007708  0.002098        13089
10    4  0.004033  0.003494  0.002998  0.007705  0.002097        14078
10    5  0.003871  0.003451  0.002998  0.007697  0.002096        15051
10    6  0.003726  0.003397  0.002998  0.007692  0.002095        16045
10    7  0.003604  0.003351  0.002999  0.007698  0.002097        16935
10    8  0.003372  0.003273  0.002998  0.007694  0.002096        18384
10    9  0.003340  0.003301  0.002998  0.007814  0.002131        19346
```

## TABLE XVIII

## TTR INPUT DATA

| PORT NO.<br>RUN PT. | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 11 | 1 | 0.000000 | 0.001360 | 0.006737 | 0.006421 | 0.006151 | 0.006081 |
| 11 | 2 | 0.000000 | 0.001360 | 0.006778 | 0.006461 | 0.006183 | 0.006130 |
| 11 | 3 | 0.000000 | 0.001359 | 0.006671 | 0.006360 | 0.006073 | 0.006019 |
| 11 | 4 | 0.000000 | 0.001359 | 0.006729 | 0.006415 | 0.006143 | 0.006073 |
| 11 | 5 | 0.000001 | 0.001359 | 0.006779 | 0.006462 | 0.006183 | 0.006125 |
| 11 | 6 | 0.000000 | 0.001357 | 0.006729 | 0.006415 | 0.006143 | 0.006076 |
| 11 | 7 | 0.000001 | 0.001356 | 0.006740 | 0.006424 | 0.006150 | 0.006090 |
| 11 | 8 | 0.000000 | 0.001353 | 0.006745 | 0.006430 | 0.006151 | 0.006091 |

| PORT NO.<br>RUN PT. | | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|
| 11 | 1 | 0.006087 | 0.006008 | 0.006090 | 0.006075 | -0.001151 | -0.002017 |
| 11 | 2 | 0.006134 | 0.006050 | 0.006136 | 0.006122 | -0.001161 | -0.001932 |
| 11 | 3 | 0.006027 | 0.005943 | 0.006028 | 0.006012 | -0.001142 | -0.001851 |
| 11 | 4 | 0.006078 | 0.005990 | 0.006079 | 0.006065 | -0.001157 | -0.001768 |
| 11 | 5 | 0.006132 | 0.006029 | 0.006134 | 0.006119 | -0.001173 | -0.001694 |
| 11 | 6 | 0.006083 | 0.005991 | 0.006088 | 0.006072 | -0.001160 | -0.001611 |
| 11 | 7 | 0.006096 | 0.005974 | 0.006102 | 0.006088 | -0.001165 | -0.001508 |
| 11 | 8 | 0.006095 | 0.005999 | 0.006096 | 0.006080 | -0.001165 | -0.001408 |

| PORT NO.<br>RUN PT. | | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|
| 11 | 1 | 0.000395 | -0.001536 | -0.001222 | -0.001828 | -0.002083 | 0.002565 |
| 11 | 2 | 0.000410 | -0.001528 | -0.001213 | -0.001654 | -0.002012 | 0.002594 |
| 11 | 3 | 0.000368 | -0.001553 | -0.001239 | -0.001396 | -0.001941 | 0.002536 |
| 11 | 4 | 0.000392 | -0.001538 | -0.001226 | -0.001197 | -0.001877 | 0.002572 |
| 11 | 5 | 0.000415 | -0.001525 | -0.001209 | -0.001015 | -0.001819 | 0.002609 |
| 11 | 6 | 0.000396 | -0.001536 | -0.001219 | -0.000757 | -0.001748 | 0.002587 |
| 11 | 7 | 0.000402 | -0.001535 | -0.001213 | -0.000678 | -0.001648 | 0.002601 |
| 11 | 8 | 0.000404 | -0.001532 | -0.001208 | -0.000576 | -0.001555 | 0.002610 |

| PORT NO.<br>RUN PT. | | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|
| 11 | 1 | 0.000874 | -0.001989 | -0.002024 | 0.001236 | -0.001027 | -0.001175 |
| 11 | 2 | 0.000884 | -0.001972 | -0.001937 | 0.001254 | -0.000942 | -0.001068 |
| 11 | 3 | 0.000853 | -0.001964 | -0.001851 | 0.001208 | -0.000864 | -0.000908 |
| 11 | 4 | 0.000863 | -0.001947 | -0.001778 | 0.001234 | -0.000751 | -0.000813 |
| 11 | 5 | 0.000872 | -0.001929 | -0.001700 | 0.001263 | -0.000615 | -0.000686 |
| 11 | 6 | 0.000855 | -0.001933 | -0.001619 | 0.001240 | -0.000497 | -0.000568 |
| 11 | 7 | 0.000863 | -0.001922 | -0.001505 | 0.001247 | -0.000416 | -0.000412 |
| 11 | 8 | 0.000860 | -0.001907 | -0.001393 | 0.001246 | -0.000340 | -0.000312 |

| PORT NO.<br>RUN PT. | | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|
| 11 | 1 | 0.000001 | 0.001360 | 0.006101 | -0.002019 | -0.001221 | -0.000940 |
| 11 | 2 | 0.000001 | 0.001359 | 0.006134 | -0.001941 | -0.001118 | -0.000831 |
| 11 | 3 | 0.000002 | 0.001360 | 0.006058 | -0.001850 | -0.001007 | -0.000725 |
| 11 | 4 | 0.000001 | 0.001359 | 0.006094 | -0.001776 | -0.000892 | -0.000611 |
| 11 | 5 | 0.000002 | 0.001359 | 0.006153 | -0.001699 | -0.000768 | -0.000481 |
| 11 | 6 | 0.000002 | 0.001358 | 0.006111 | -0.001614 | -0.000642 | -0.000370 |
| 11 | 7 | 0.000002 | 0.001355 | 0.006113 | -0.001510 | -0.000527 | -0.000302 |
| 11 | 8 | 0.000002 | 0.001354 | 0.006113 | -0.001400 | -0.000432 | -0.000220 |

```
PORT NO.        31         32         33         34         35         36
RUN PT.
11   1    -0.000983 -0.000852 -0.000830 -0.000915 -0.000866 -0.000709
11   2    -0.000871 -0.000751 -0.000728 -0.000814 -0.000824 -0.000738
11   3    -0.000782 -0.000675 -0.000694 -0.000785 -0.000755 -0.000699
11   4    -0.000701 -0.000609 -0.000653 -0.000788 -0.000778 -0.000668
11   5    -0.000610 -0.000577 -0.000589 -0.000719 -0.000771 -0.000670
11   6    -0.000522 -0.000503 -0.000583 -0.000767 -0.000821 -0.000680
11   7    -0.000457 -0.000417 -0.000465 -0.000655 -0.000738 -0.000682
11   8    -0.000384 -0.000345 -0.000389 -0.000610 -0.000718 -0.000651

PORT NO.        37         38         39         40         41         42
RUN PT.
11   1    -0.001102 -0.001193 -0.001137 -0.001167 -0.001151 -0.001164
11   2    -0.001151 -0.001225 -0.001138 -0.001172 -0.001181 -0.001185
11   3    -0.001135 -0.001210 -0.001134 -0.001168 -0.001165 -0.001181
11   4    -0.001140 -0.001230 -0.001152 -0.001184 -0.001182 -0.001186
11   5    -0.001131 -0.001256 -0.001167 -0.001198 -0.001205 -0.001204
11   6    -0.001116 -0.001246 -0.001156 -0.001197 -0.001201 -0.001200
11   7    -0.001141 -0.001268 -0.001144 -0.001192 -0.001200 -0.001200
11   8    -0.001142 -0.001278 -0.001140 -0.001186 -0.001193 -0.001196

PORT NO.        43         44         45         46         47         48
RUN PT.
11   1    -0.001158 -0.001142 -0.001177 -0.001178  0.000000  0.000000
11   2    -0.001176 -0.001157 -0.001176 -0.001176  0.000000  0.000000
11   3    -0.001171 -0.001154 -0.001158 -0.001158  0.000000  0.000000
11   4    -0.001181 -0.001173 -0.001169 -0.001169  0.000000  0.000000
11   5    -0.001191 -0.001189 -0.001182 -0.001181  0.000000  0.000000
11   6    -0.001184 -0.001180 -0.001173 -0.001173  0.000000  0.000000
11   7    -0.001184 -0.001182 -0.001175 -0.001175  0.000000  0.000000
11   8    -0.001178 -0.001178 -0.001171 -0.001170  0.000000  0.000000

CHANNEL        0          1          2          3          4          RPM
RUN PT
11   1   0.005132  0.004811  0.004403  0.003593  0.004339      11129
11   2   0.005129  0.004809  0.004398  0.003591  0.004338      12155
11   3   0.005112  0.004800  0.004379  0.003592  0.004327      13123
11   4   0.005084  0.004771  0.004349  0.003584  0.004296      14027
11   5   0.005091  0.004770  0.004334  0.003600  0.004281      15000
11   6   0.005079  0.004767  0.004329  0.003602  0.004278      15829
11   7   0.005074  0.004759  0.004329  0.003620  0.004267      16862
11   8   0.005077  0.004762  0.004328  0.003635  0.004266      18017

CHANNEL        5          6         20          21         23          RPM
RUN PT
11   1   0.000769  0.002750 -0.001523  0.000730  0.005585      11129
11   2   0.000540  0.002669 -0.001348  0.000883  0.005413      12155
11   3   0.000327  0.002740 -0.001183  0.001099  0.005178      13123
11   4   0.000211  0.002602 -0.000988  0.001273  0.005045      14027
11   5   0.000164  0.002567 -0.000802  0.001556  0.004853      15000
11   6   0.000124  0.002725 -0.000655  0.001734  0.004695      15829
11   7 -0.000044  0.002918 -0.000391  0.001764  0.004474      16862
11   8  0.000004  0.002978 -0.000082  0.002010  0.004262      18017
```

```
CHANNEL       23         24         25         26         27          RPM
RUN PT
11    1  0.005585  0.004510  0.002998  0.008009  0.003185       11129
11    2  0.005413  0.004464  0.002998  0.008001  0.003181       12155
11    3  0.005178  0.004360  0.002998  0.007944  0.003157       13123
11    4  0.005045  0.004342  0.002997  0.007984  0.003175       14027
11    5  0.004853  0.004300  0.002997  0.008006  0.003186       15000
11    6  0.004695  0.004229  0.002998  0.007978  0.003174       15829
11    7  0.004474  0.004158  0.002997  0.007980  0.003176       16862
11    8  0.004262  0.004099  0.002998  0.008000  0.003188       18017
```

## TABLE XIX

## TTR INPUT DATA

| PORT NO. | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 12 | 1 | 0.000000 | 0.001358 | 0.006216 | 0.006009 | 0.004118 | 0.004078 |
| 12 | 2 | 0.000000 | 0.001357 | 0.006178 | 0.005972 | 0.004103 | 0.004047 |
| 12 | 3 | 0.000000 | 0.001358 | 0.006215 | 0.006007 | 0.004121 | 0.004078 |
| 12 | 4 | 0.000000 | 0.001357 | 0.006209 | 0.006001 | 0.004120 | 0.004078 |
| 12 | 5 | 0.000000 | 0.001357 | 0.006203 | 0.005995 | 0.004114 | 0.004069 |
| 12 | 6 | 0.000000 | 0.001357 | 0.006182 | 0.005974 | 0.004102 | 0.004054 |

| PORT NO. | | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 12 | 1 | 0.004082 | 0.004022 | 0.004083 | 0.004071 | -0.001762 | -0.002237 |
| 12 | 2 | 0.004054 | 0.003996 | 0.004056 | 0.004044 | -0.001760 | -0.002107 |
| 12 | 3 | 0.004082 | 0.004016 | 0.004081 | 0.004070 | -0.001759 | -0.001882 |
| 12 | 4 | 0.004083 | 0.004019 | 0.004084 | 0.004070 | -0.001763 | -0.001799 |
| 12 | 5 | 0.004075 | 0.004011 | 0.004076 | 0.004065 | -0.001762 | -0.001665 |
| 12 | 6 | 0.004061 | 0.003999 | 0.004061 | 0.004051 | -0.001761 | -0.001591 |

| PORT NO. | | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 12 | 1 | -0.000490 | -0.001939 | -0.001564 | -0.002007 | -0.002314 | 0.001328 |
| 12 | 2 | -0.000501 | -0.001951 | -0.001581 | -0.001808 | -0.002205 | 0.001311 |
| 12 | 3 | -0.000488 | -0.001946 | -0.001567 | -0.001352 | -0.002002 | 0.001329 |
| 12 | 4 | -0.000483 | -0.001942 | -0.001549 | -0.001237 | -0.001941 | 0.001333 |
| 12 | 5 | -0.000484 | -0.001952 | -0.001563 | -0.001032 | -0.001841 | 0.001331 |
| 12 | 6 | -0.000491 | -0.001958 | -0.001562 | -0.000849 | -0.001772 | 0.001321 |

| PORT NO. | | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 12 | 1 | -0.000041 | -0.002180 | -0.002239 | 0.000194 | -0.001210 | -0.001461 |
| 12 | 2 | -0.000066 | -0.002189 | -0.002113 | 0.000178 | -0.001109 | -0.001312 |
| 12 | 3 | -0.000053 | -0.002164 | -0.001874 | 0.000194 | -0.000936 | -0.001031 |
| 12 | 4 | -0.001753 | -0.002152 | -0.001816 | 0.000196 | -0.000883 | -0.000981 |
| 12 | 5 | -0.001767 | -0.002149 | -0.001689 | 0.000193 | -0.000803 | -0.000935 |
| 12 | 6 | -0.001765 | -0.002140 | -0.001580 | 0.000185 | -0.000743 | -0.000770 |

| PORT NO. | | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 12 | 1 | 0.000000 | 0.001358 | 0.004092 | -0.002234 | -0.001540 | -0.001280 |
| 12 | 2 | 0.000000 | 0.001357 | 0.004055 | -0.002116 | -0.001378 | -0.001092 |
| 12 | 3 | 0.000000 | 0.001357 | 0.004079 | -0.001865 | -0.001090 | -0.000878 |
| 12 | 4 | 0.000000 | 0.001357 | 0.004081 | -0.001807 | -0.001025 | -0.000814 |
| 12 | 5 | 0.000000 | 0.001357 | 0.004077 | -0.001746 | -0.000971 | -0.000752 |
| 12 | 6 | -0.000001 | 0.001357 | 0.004056 | -0.001579 | -0.000846 | -0.000663 |

| PORT NO. | | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 12 | 1 | -0.001271 | -0.001237 | -0.001287 | -0.001365 | -0.001365 | -0.001301 |
| 12 | 2 | -0.001168 | -0.001171 | -0.001239 | -0.001354 | -0.001404 | -0.001313 |
| 12 | 3 | -0.000983 | -0.000996 | -0.001126 | -0.001316 | -0.001399 | -0.001319 |
| 12 | 4 | -0.000922 | -0.000959 | -0.001078 | -0.001286 | -0.001375 | -0.001319 |
| 12 | 5 | -0.000860 | -0.000918 | -0.001033 | -0.001247 | -0.001351 | -0.001319 |
| 12 | 6 | -0.000769 | -0.000857 | -0.000970 | -0.001191 | -0.001299 | -0.001309 |

```
PORT NO.     37        38        39        40        41        42
RUN PT.
12   1    -0.001745 -0.001774 -0.001722 -0.001760 -0.001791 -0.001786
12   2    -0.001717 -0.001779 -0.001719 -0.001765 -0.001771 -0.001767
12   3    -0.001735 -0.001819 -0.001750 -0.001804 -0.001792 -0.001789
12   4    -0.001746 -0.001833 -0.001741 -0.001724 -0.001791 -0.001793
12   5    -0.001760 -0.001851 -0.001746 -0.001778 -0.001802 -0.001798
12   6    -0.001767 -0.001875 -0.001763 -0.001777 -0.001767 -0.001796

PORT NO.     43        44        45        46        47        48
RUN PT.
12   1    -0.001778 -0.001764 -0.001776 -0.001776  0.000000  0.000000
12   2    -0.001766 -0.001760 -0.001756 -0.001757  0.000000  0.000000
12   3    -0.001776 -0.001775 -0.001769 -0.001769  0.000000  0.000000
12   4    -0.001773 -0.001775 -0.001770 -0.001770  0.000000 -0.000001
12   5    -0.001774 -0.001776 -0.001772 -0.001773  0.000000  0.000000
12   6    -0.001768 -0.001771 -0.001770 -0.001770  0.000000  0.000000

CHANNEL      0         1         2         3         4           RPM
RUN PT
12   1   0.002623  0.002555  0.002427  0.001847  0.002349      12214
12   2   0.002638  0.002545  0.002366  0.001785  0.002302      13817
12   3   0.002667  0.002554  0.002347  0.001802  0.002284      16003
12   4   0.002677  0.002561  0.002337  0.001816  0.002273      16964
12   5   0.002642  0.002546  0.002326  0.001821  0.002266      17755
12   6   0.002636  0.002534  0.002308  0.001812  0.002255      19046

CHANNEL      5         6        20        21        23           RPM
RUN PT
12   1 -0.000440  0.001369 -0.000732  0.000877  0.004223      12214
12   2 -0.000587  0.001461 -0.000469  0.001187  0.003915      13817
12   3 -0.000650  0.001300  0.000069  0.001545  0.003554      16003
12   4 -0.000686  0.001271  0.000277  0.001808  0.003332      16964
12   5 -0.000749  0.001365  0.000467  0.002026  0.003127      17755
12   6 -0.000801  0.001373  0.000727  0.002255  0.003089      19046

CHANNEL     23        24        25        26        27           RPM
RUN PT
12   1   0.004223  0.003506  0.002997  0.007599  0.002080      12214
12   2   0.003915  0.003415  0.002998  0.007577  0.002078      13817
12   3   0.003554  0.003287  0.002997  0.007594  0.002088      16003
12   4   0.003332  0.003207  0.002998  0.007589  0.002088      16964
12   5   0.003127  0.003151  0.002998  0.007593  0.002088      17755
12   6   0.003089  0.003104  0.002998  0.007584  0.002085      19046
```

## TABLE XX

## TTR INPUT DATA

| PORT NO. | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 13 | 1 | -0.000002 | 0.001353 | 0.006283 | 0.006072 | 0.004143 | 0.004104 |
| 13 | 2 | -0.000001 | 0.001353 | 0.006262 | 0.006053 | 0.004141 | 0.004091 |
| 13 | 3 | -0.000002 | 0.001353 | 0.006281 | 0.006070 | 0.004141 | 0.004097 |
| 13 | 4 | -0.000002 | 0.001353 | 0.006274 | 0.006065 | 0.004137 | 0.004091 |
| 13 | 5 | -0.000001 | 0.001353 | 0.006256 | 0.006045 | 0.004130 | 0.004076 |
| 13 | 6 | -0.000003 | 0.001353 | 0.006268 | 0.006059 | 0.004138 | 0.004088 |
| 13 | 7 | 0.000000 | 0.001355 | 0.006281 | 0.006069 | 0.004140 | 0.004096 |
| 13 | 8 | 0.000000 | 0.001353 | 0.006260 | 0.006051 | 0.004129 | 0.004081 |

| PORT NO. | | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 13 | 1 | 0.004111 | 0.000007 | 0.004107 | 0.004096 | -0.001778 | -0.002225 |
| 13 | 2 | 0.004095 | 0.004002 | 0.004096 | 0.004083 | -0.001757 | -0.002173 |
| 13 | 3 | 0.004102 | 0.004008 | 0.004103 | 0.004092 | -0.001773 | -0.002098 |
| 13 | 4 | 0.004097 | 0.003930 | 0.004097 | 0.004086 | -0.001772 | -0.002017 |
| 13 | 5 | 0.004082 | 0.003951 | 0.004084 | 0.004073 | -0.001772 | -0.001895 |
| 13 | 6 | 0.004093 | 0.003968 | 0.004096 | 0.004086 | -0.001778 | -0.001778 |
| 13 | 7 | 0.004103 | 0.003983 | 0.004104 | 0.004092 | -0.001779 | -0.001628 |
| 13 | 8 | 0.004087 | 0.000008 | 0.004083 | 0.004071 | -0.001776 | -0.001532 |

| PORT NO. | | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 13 | 1 | -0.000483 | -0.001942 | -0.001521 | -0.001939 | -0.002309 | 0.001354 |
| 13 | 2 | -0.000489 | -0.001978 | -0.001599 | -0.001887 | -0.002260 | 0.001348 |
| 13 | 3 | -0.000486 | -0.001971 | -0.001586 | -0.001715 | -0.002198 | 0.001353 |
| 13 | 4 | -0.000489 | -0.001979 | -0.001593 | -0.001513 | -0.002130 | 0.001349 |
| 13 | 5 | -0.000492 | -0.001949 | -0.001510 | -0.001341 | -0.002019 | 0.001340 |
| 13 | 6 | -0.000486 | -0.001958 | -0.001542 | -0.001185 | -0.001933 | 0.001352 |
| 13 | 7 | -0.000483 | -0.001972 | -0.001562 | -0.000909 | -0.001817 | 0.001356 |
| 13 | 8 | -0.000488 | -0.001952 | -0.001482 | -0.000595 | -0.001717 | 0.001349 |

| PORT NO. | | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 13 | 1 | -0.001774 | -0.002184 | -0.002230 | 0.000189 | -0.001204 | -0.001483 |
| 13 | 2 | -0.001754 | -0.002211 | -0.002179 | 0.000181 | -0.001145 | -0.001387 |
| 13 | 3 | -0.001768 | -0.002200 | -0.002104 | 0.000184 | -0.001075 | -0.001289 |
| 13 | 4 | -0.001772 | -0.002198 | -0.002019 | 0.000182 | -0.000989 | -0.001192 |
| 13 | 5 | -0.001773 | -0.002163 | -0.001895 | 0.000176 | -0.000951 | -0.001067 |
| 13 | 6 | -0.001776 | -0.002157 | -0.001778 | 0.000185 | -0.000862 | -0.000939 |
| 13 | 7 | -0.001779 | -0.002151 | -0.001625 | 0.000187 | -0.000731 | -0.000791 |
| 13 | 8 | -0.001781 | -0.002100 | -0.001522 | 0.000180 | -0.000632 | -0.000706 |

| PORT NO. | | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 13 | 1 | -0.000002 | 0.001353 | 0.004111 | -0.002231 | -0.001473 | -0.001151 |
| 13 | 2 | 0.000000 | 0.001353 | 0.004102 | -0.002176 | -0.001450 | -0.001171 |
| 13 | 3 | 0.000000 | 0.001354 | 0.004101 | -0.002101 | -0.001333 | -0.001055 |
| 13 | 4 | 0.000000 | 0.001353 | 0.004107 | -0.002016 | -0.001210 | -0.000959 |
| 13 | 5 | 0.000000 | 0.001354 | 0.004084 | -0.001889 | -0.001082 | -0.000855 |
| 13 | 6 | 0.000000 | 0.001354 | 0.004113 | -0.001779 | -0.000988 | -0.000782 |
| 13 | 7 | -0.000001 | 0.001354 | 0.004111 | -0.001626 | -0.000862 | -0.000671 |
| 13 | 8 | -0.000001 | 0.001353 | 0.004100 | -0.001520 | -0.000694 | -0.000521 |

```
PORT NO.      31         32         33         34         35         36
RUN PT.
13   1    -0.001219 -0.001212 -0.001238 -0.001327 -0.001318 -0.001228
13   2    -0.001216 -0.001201 -0.001275 -0.001387 -0.001316 -0.001178
13   3    -0.001149 -0.001148 -0.001221 -0.001340 -0.001338 -0.001208
13   4    -0.001074 -0.001085 -0.001174 -0.001334 -0.001352 -0.001212
13   5    -0.000979 -0.000990 -0.001094 -0.001271 -0.001319 -0.001207
13   6    -0.000895 -0.000930 -0.001037 -0.001252 -0.001324 -0.001201
13   7    -0.000778 -0.000840 -0.000957 -0.001197 -0.001284 -0.001212
13   8    -0.000655 -0.000754 -0.000911 -0.001150 -0.001292 -0.001280

PORT NO.      37         38         39         40         41         42
RUN PT.
13   1    -0.001672 -0.001698 -0.001722 -0.001718 -0.001738 -0.001794
13   2    -0.001747 -0.001768 -0.001756 -0.001756 -0.001752 -0.001785
13   3    -0.001734 -0.001775 -0.001770 -0.001785 -0.001778 -0.001789
13   4    -0.001710 -0.001763 -0.001763 -0.001775 -0.001776 -0.001788
13   5    -0.001727 -0.001776 -0.001760 -0.001781 -0.001778 -0.001785
13   6    -0.001763 -0.001809 -0.001765 -0.001793 -0.001777 -0.001784
13   7    -0.001787 -0.001869 -0.001782 -0.001796 -0.001776 -0.001811
13   8    -0.001784 -0.001875 -0.001777 -0.001784 -0.001786 -0.001805

PORT NO.      43         44         45         46         47         48
RUN PT.
13   1    -0.001775 -0.001762 -0.001784 -0.001786 -0.000003 -0.000002
13   2    -0.001777 -0.001758 -0.001765 -0.001764  0.000000  0.000000
13   3    -0.001793 -0.001785 -0.001782 -0.001782 -0.000001 -0.000002
13   4    -0.001785 -0.001778 -0.001774 -0.001774 -0.000001 -0.000001
13   5    -0.001785 -0.001782 -0.001779 -0.001778 -0.000001  0.000000
13   6    -0.001791 -0.001792 -0.001788 -0.001788 -0.000002 -0.000001
13   7    -0.001789 -0.001788 -0.001790 -0.001791 -0.000001 -0.000001
13   8    -0.001785 -0.001781 -0.001788 -0.001788 -0.000001 -0.000001

CHANNEL      0          1          2          3          4          RPM
RUN PT
13   1   0.002790   0.002665   0.002409   0.001833   0.002354     12085
13   2   0.002753   0.002623   0.002369   0.001807   0.002309     13081
13   3   0.002758   0.002633   0.002367   0.001805   0.002313     14070
13   4   0.002764   0.002637   0.002367   0.001805   0.002319     14995
13   5   0.002774   0.002646   0.002393   0.001843   0.002324     16044
13   6   0.002778   0.002644   0.002390   0.001857   0.002327     17032
13   7   0.002785   0.002658   0.002405   0.001881   0.002351     18953
13   8   0.002783   0.002661   0.002412   0.001912   0.002359     20009

CHANNEL      5          6          20         21         23         RPM
RUN PT
13   1 -0.000232   0.001177 -0.000696   0.001030   0.004170     12085
13   2 -0.000535   0.001238 -0.000606   0.001013   0.004055     13081
13   3 -0.000440   0.001104 -0.000405   0.001226   0.003903     14070
13   4 -0.000425   0.001093 -0.000231   0.001409   0.003731     14995
13   5 -0.000449   0.001310  0.000077   0.001591   0.003523     16044
13   6 -0.000431   0.001328  0.000303   0.001852   0.003376     17032
13   7 -0.000396   0.001382  0.000640   0.002253   0.003085     18953
13   8 -0.000456   0.001583  0.000863   0.002410   0.002894     20009

CHANNEL      23         24         25         26         27         RPM
RUN PT
13   1   0.004170   0.003489   0.003001   0.007600   0.002109     12085
13   2   0.004055   0.003451   0.003003   0.007597   0.002106     13081
13   3   0.003903   0.003421   0.003003   0.007614   0.002112     14070
13   4   0.003731   0.003366   0.003003   0.007608   0.002109     14995
13   5   0.003523   0.003256   0.003003   0.007600   0.002108     16044
13   6   0.003376   0.003216   0.003002   0.007608   0.002111     17032
13   7   0.003085   0.003074   0.003003   0.007607   0.002109     18953
13   8   0.002894   0.003025   0.003002   0.007601   0.002110     20009
```

## TABLE XXI

## TTR INPUT DATA

| PORT NO. | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 14 | 1 | -0.000003 | 0.001350 | 0.006251 | 0.006044 | 0.004080 | 0.004025 |
| 14 | 2 | 0.000001 | 0.001363 | 0.006339 | 0.006131 | 0.004144 | 0.004099 |
| 14 | 3 | 0.000000 | 0.001362 | 0.006322 | 0.006114 | 0.004135 | 0.004083 |
| 14 | 4 | 0.000001 | 0.001363 | 0.006315 | 0.006107 | 0.004133 | 0.004085 |
| 14 | 5 | 0.000000 | 0.001362 | 0.006357 | 0.006147 | 0.004154 | 0.004109 |
| 14 | 6 | 0.000001 | 0.001361 | 0.006303 | 0.006092 | 0.004115 | 0.004065 |
| 14 | 7 | 0.000000 | 0.001362 | 0.006322 | 0.006113 | 0.004130 | 0.004082 |
| 14 | 8 | 0.000002 | 0.001362 | 0.006338 | 0.006130 | 0.004139 | 0.004094 |

| PORT NO. | | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 14 | 1 | 0.004032 | 0.003940 | 0.004033 | 0.004024 | -0.001734 | -0.002310 |
| 14 | 2 | 0.004105 | 0.004009 | 0.004106 | 0.004097 | -0.001761 | -0.002239 |
| 14 | 3 | 0.004088 | 0.003996 | 0.004091 | 0.004079 | -0.001755 | -0.002170 |
| 14 | 4 | 0.004089 | 0.003994 | 0.004091 | 0.004079 | -0.001758 | -0.002093 |
| 14 | 5 | 0.004117 | 0.004023 | 0.004118 | 0.004108 | -0.001775 | -0.002003 |
| 14 | 6 | 0.004069 | 0.003980 | 0.004071 | 0.004059 | -0.001757 | -0.001928 |
| 14 | 7 | 0.004088 | 0.003998 | 0.004090 | 0.004081 | -0.001765 | -0.001762 |
| 14 | 8 | 0.004099 | 0.004008 | 0.004098 | 0.004087 | -0.001770 | -0.001610 |

| PORT NO. | | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 14 | 1 | -0.000520 | -0.002068 | -0.001730 | -0.001950 | -0.002379 | 0.001279 |
| 14 | 2 | -0.000485 | -0.002046 | -0.001691 | -0.001853 | -0.002324 | 0.001330 |
| 14 | 3 | -0.000492 | -0.002049 | -0.001702 | -0.001714 | -0.002261 | 0.001318 |
| 14 | 4 | -0.000493 | -0.002051 | -0.001708 | -0.001529 | -0.002211 | 0.001322 |
| 14 | 5 | -0.000479 | -0.002043 | -0.001683 | -0.001409 | -0.002120 | 0.001342 |
| 14 | 6 | -0.000496 | -0.002055 | -0.001704 | -0.001293 | -0.002049 | 0.001313 |
| 14 | 7 | -0.000487 | -0.002049 | -0.001689 | -0.001074 | -0.001915 | 0.001330 |
| 14 | 8 | -0.000481 | -0.002046 | -0.001653 | -0.000716 | -0.001788 | 0.001340 |

| PORT NO. | | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 14 | 1 | -0.000045 | -0.002332 | -0.002311 | 0.000135 | -0.001560 | -0.001588 |
| 14 | 2 | -0.000020 | -0.002302 | -0.002247 | 0.000174 | -0.001463 | -0.001480 |
| 14 | 3 | -0.000035 | -0.002307 | -0.002170 | 0.000162 | -0.001384 | -0.001381 |
| 14 | 4 | -0.000041 | -0.002306 | -0.002104 | 0.000164 | -0.001274 | -0.001291 |
| 14 | 5 | -0.000068 | -0.002281 | -0.002013 | 0.000181 | -0.001198 | -0.001189 |
| 14 | 6 | -0.000031 | -0.002284 | -0.001924 | 0.000154 | -0.001140 | -0.001064 |
| 14 | 7 | -0.000061 | -0.002260 | -0.001751 | 0.000164 | -0.001027 | -0.000923 |
| 14 | 8 | -0.000124 | -0.002210 | -0.001616 | 0.000168 | -0.000862 | -0.000799 |

| PORT NO. | | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 14 | 1 | -0.000002 | 0.001351 | 0.004050 | -0.002312 | -0.001667 | -0.001440 |
| 14 | 2 | 0.000000 | 0.001362 | 0.004122 | -0.002244 | -0.001569 | -0.001330 |
| 14 | 3 | 0.000001 | 0.001362 | 0.004098 | -0.002170 | -0.001463 | -0.001217 |
| 14 | 4 | 0.000000 | 0.001362 | 0.004094 | -0.002097 | -0.001340 | -0.001114 |
| 14 | 5 | 0.000001 | 0.001362 | 0.004124 | -0.002020 | -0.001242 | -0.001039 |
| 14 | 6 | 0.000002 | 0.001362 | 0.004075 | -0.001919 | -0.001150 | -0.000980 |
| 14 | 7 | 0.000000 | 0.001361 | 0.004099 | -0.001750 | -0.001004 | -0.000860 |
| 14 | 8 | 0.000000 | 0.001361 | 0.004099 | -0.001612 | -0.000841 | -0.000695 |

```
PORT NO.     31        32        33        34        35        36
RUN PT.
14   1    -0.001448 -0.001363 -0.001338 -0.001400 -0.001406 -0.001316
14   2    -0.001350 -0.001285 -0.001300 -0.001388 -0.001371 -0.001298
14   3    -0.001287 -0.001239 -0.001251 -0.001356 -0.001410 -0.001303
14   4    -0.001249 -0.001221 -0.001239 -0.001342 -0.001380 -0.001296
14   5    -0.001165 -0.001112 -0.001153 -0.001286 -0.001387 -0.001320
14   6    -0.001110 -0.001071 -0.001085 -0.001259 -0.001328 -0.001291
14   7    -0.000975 -0.000942 -0.000973 -0.001195 -0.001281 -0.001266
14   8    -0.000806 -0.000754 -0.000828 -0.001060 -0.001188 -0.001208

PORT NO.     37        38        39        40        41        42
RUN PT.
14   1    -0.001708 -0.001693 -0.001721 -0.001713 -0.001731 -0.001773
14   2    -0.001738 -0.001734 -0.001756 -0.001766 -0.001752 -0.001795
14   3    -0.001704 -0.001725 -0.001746 -0.001758 -0.001760 -0.001788
14   4    -0.001705 -0.001726 -0.001734 -0.001752 -0.001756 -0.001780
14   5    -0.001727 -0.001765 -0.001750 -0.001774 -0.001775 -0.001799
14   6    -0.001737 -0.001762 -0.001725 -0.001749 -0.001756 -0.001778
14   7    -0.001766 -0.001837 -0.001756 -0.001768 -0.001772 -0.001790
14   8    -0.001757 -0.001854 -0.001766 -0.001775 -0.001777 -0.001801

PORT NO.     43        44        45        46        47        48
RUN PT.
14   1    -0.001745 -0.001728 -0.001745 -0.001745 -0.000004 -0.000003
14   2    -0.001789 -0.001774 -0.001780 -0.001780  0.000000  0.000000
14   3    -0.001768 -0.001766 -0.001767 -0.001767  0.000001  0.000002
14   4    -0.001763 -0.001760 -0.001764 -0.001763  0.000000  0.000001
14   5    -0.001782 -0.001780 -0.001779 -0.001780  0.000000  0.000001
14   6    -0.001758 -0.001757 -0.001754 -0.001754  0.000001  0.000001
14   7    -0.001768 -0.001767 -0.001767 -0.001767  0.000001  0.000001
14   8    -0.001777 -0.001776 -0.001780 -0.001782  0.000000  0.000000

CHANNEL     0         1         2         3         4          RPM
RUN PT
14   1   0.003768  0.003589  0.003287  0.002579  0.003207     12075
14   2   0.003779  0.003580  0.003258  0.002556  0.003179     13120
14   3   0.003774  0.003583  0.003246  0.002572  0.003178     14109
14   4   0.003780  0.003582  0.003224  0.002556  0.003173     15023
14   5   0.003783  0.003587  0.003234  0.002582  0.003172     16078
14   6   0.003780  0.003587  0.003238  0.002608  0.003172     17074
14   7   0.003782  0.003589  0.003241  0.002638  0.003187     18917
14   8   0.003789  0.003598  0.003235  0.002655  0.003188     19987

CHANNEL     5         6         20        21        23         RPM
RUN PT
14   1 -0.000182  0.002011 -0.000984  0.000831  0.004171     12075
14   2 -0.000284  0.001853 -0.000764  0.001001  0.004103     13120
14   3 -0.000306  0.001803 -0.000565  0.001179  0.003926     14109
14   4 -0.000377  0.001847 -0.000460  0.001463  0.003750     15023
14   5 -0.000412  0.001854 -0.000206  0.001436  0.003632     16078
14   6 -0.000374  0.001986 -0.000052  0.001591  0.003421     17074
14   7 -0.000374  0.002123  0.000354  0.002022  0.003110     18917
14   8 -0.000312  0.002019  0.000631  0.002233  0.002984     19987

CHANNEL     23        24        25        26        27         RPM
RUN PT
14   1   0.004171  0.003515  0.003002  0.007604  0.002089     12075
14   2   0.004103  0.003501  0.002996  0.007649  0.002100     13120
14   3   0.003926  0.003457  0.002996  0.007651  0.002103     14109
14   4   0.003750  0.003409  0.002996  0.007636  0.002099     15023
14   5   0.003632  0.003358  0.002995  0.007658  0.002106     16078
14   6   0.003421  0.003271  0.002995  0.007620  0.002094     17074
14   7   0.003110  0.003159  0.002995  0.007639  0.002100     18917
14   8   0.002984  0.003100  0.002996  0.007644  0.002105     19987
```

# TABLE XXII

## TTR INPUT DATA

| PORT NO. | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 15 | 1 | 0.000000 | 0.001361 | 0.006490 | 0.006281 | 0.004148 | 0.004103 |
| 15 | 2 | -0.000002 | 0.001359 | 0.006486 | 0.000104 | 0.004135 | 0.004087 |
| 15 | 3 | 0.000000 | 0.001360 | 0.006480 | 0.000154 | 0.004125 | 0.004074 |
| 15 | 4 | 0.000000 | 0.001359 | 0.006482 | 0.000162 | 0.004119 | 0.004072 |
| 15 | 5 | -0.000001 | 0.001359 | 0.006513 | 0.000182 | 0.004152 | 0.004101 |
| 15 | 6 | 0.000000 | 0.001359 | 0.006526 | 0.000198 | 0.004151 | 0.004107 |
| 15 | 7 | 0.000000 | 0.001361 | 0.006485 | 0.000206 | 0.004125 | 0.004069 |
| 15 | 8 | 0.000000 | 0.001360 | 0.006487 | 0.000212 | 0.004124 | 0.004071 |

| PORT NO. | | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 15 | 1 | 0.004106 | 0.004005 | 0.004105 | 0.004093 | -0.001794 | -0.002425 |
| 15 | 2 | 0.004091 | 0.003994 | 0.004092 | 0.004082 | -0.001790 | -0.002371 |
| 15 | 3 | 0.004080 | 0.003985 | 0.004082 | 0.004072 | -0.001787 | -0.002315 |
| 15 | 4 | 0.004078 | 0.003981 | 0.004078 | 0.004066 | -0.001797 | -0.002261 |
| 15 | 5 | 0.004106 | 0.004007 | 0.004104 | 0.004093 | -0.001803 | -0.002202 |
| 15 | 6 | 0.004112 | 0.004012 | 0.004109 | 0.004097 | -0.001810 | -0.002138 |
| 15 | 7 | 0.004075 | 0.003980 | 0.004076 | 0.004068 | -0.001801 | -0.001979 |
| 15 | 8 | 0.004076 | 0.003980 | 0.004073 | 0.004062 | -0.001797 | -0.001893 |

| PORT NO. | | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 15 | 1 | -0.000489 | -0.002051 | -0.001785 | -0.002353 | -0.002487 | 0.001308 |
| 15 | 2 | -0.000490 | -0.002052 | -0.001786 | -0.002255 | -0.002440 | 0.001307 |
| 15 | 3 | -0.000492 | -0.002053 | -0.001786 | -0.002128 | -0.002395 | 0.001304 |
| 15 | 4 | -0.000495 | -0.002054 | -0.001787 | -0.001995 | -0.002349 | 0.001302 |
| 15 | 5 | -0.000482 | -0.002047 | -0.001780 | -0.001833 | -0.002302 | 0.001320 |
| 15 | 6 | -0.000480 | -0.002046 | -0.001778 | -0.001676 | -0.002234 | 0.001323 |
| 15 | 7 | -0.000491 | -0.002053 | -0.001780 | -0.001413 | -0.002109 | 0.001313 |
| 15 | 8 | -0.000494 | -0.002055 | -0.001779 | -0.001281 | -0.002038 | 0.001314 |

| PORT NO. | | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 15 | 1 | -0.000034 | -0.002430 | -0.002435 | 0.000115 | -0.001682 | -0.001724 |
| 15 | 2 | -0.000037 | -0.002425 | -0.002378 | 0.000109 | -0.001626 | -0.001646 |
| 15 | 3 | -0.000038 | -0.002421 | -0.002326 | 0.000109 | -0.001560 | -0.001573 |
| 15 | 4 | -0.000042 | -0.002417 | -0.002266 | 0.000109 | -0.001483 | -0.001493 |
| 15 | 5 | -0.000038 | -0.002411 | -0.002208 | 0.000120 | -0.001380 | -0.001385 |
| 15 | 6 | -0.000042 | -0.002399 | -0.002138 | 0.000122 | -0.001313 | -0.001319 |
| 15 | 7 | -0.000051 | -0.002371 | -0.001983 | 0.000111 | -0.001185 | -0.001095 |
| 15 | 8 | -0.000054 | -0.002350 | -0.001893 | 0.000110 | -0.001138 | -0.001034 |

| PORT NO. | | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|
| RUN | PT. | | | | | | |
| 15 | 1 | -0.000001 | 0.001359 | 0.004124 | -0.002433 | -0.001803 | -0.001585 |
| 15 | 2 | 0.000000 | 0.001360 | 0.004106 | -0.002376 | -0.001723 | -0.001495 |
| 15 | 3 | 0.000000 | 0.001360 | 0.004097 | -0.002322 | -0.001637 | -0.001422 |
| 15 | 4 | 0.000000 | 0.001360 | 0.004106 | -0.002264 | -0.001548 | -0.001337 |
| 15 | 5 | 0.000000 | 0.001360 | 0.004112 | -0.002202 | -0.001446 | -0.001216 |
| 15 | 6 | 0.000000 | 0.001360 | 0.004103 | -0.002136 | -0.001371 | -0.001134 |
| 15 | 7 | 0.000000 | 0.001359 | 0.004079 | -0.001978 | -0.001201 | -0.001035 |
| 15 | 8 | 0.000000 | 0.001360 | 0.004082 | -0.001885 | -0.001131 | -0.000976 |

```
PORT NO.      31          32          33          34          35          36
RUN PT.
15    1    -0.001576 -0.001460 -0.001447 -0.001524 -0.001515 -0.001384
15    2    -0.001490 -0.001399 -0.001408 -0.001475 -0.001467 -0.001379
15    3    -0.001421 -0.001342 -0.001380 -0.001491 -0.001442 -0.001378
15    4    -0.001357 -0.001331 -0.001332 -0.001472 -0.001510 -0.001384
15    5    -0.001276 -0.001302 -0.001350 -0.001501 -0.001493 -0.001406
15    6    -0.001238 -0.001245 -0.001297 -0.001429 -0.001492 -0.001423
15    7    -0.001161 -0.001147 -0.001181 -0.001346 -0.001429 -0.001393
15    8    -0.001111 -0.001107 -0.001121 -0.001315 -0.001396 -0.001376

PORT NO.      37          38          39          40          41          42
RUN PT.
15    1    -0.001751 -0.001730 -0.001779 -0.001783 -0.001785 -0.001836
15    2    -0.001768 -0.001759 -0.001788 -0.001783 -0.001785 -0.001846
15    3    -0.001773 -0.001763 -0.001793 -0.001799 -0.001785 -0.001833
15    4    -0.001774 -0.001775 -0.001799 -0.001813 -0.001795 -0.001836
15    5    -0.001774 -0.001801 -0.001806 -0.001818 -0.001811 -0.001836
15    6    -0.001792 -0.001815 -0.001797 -0.001818 -0.001816 -0.001833
15    7    -0.001815 -0.001864 -0.001787 -0.001806 -0.001806 -0.001827
15    8    -0.001815 -0.001888 -0.001796 -0.001806 -0.001806 -0.001823

PORT NO.      43          44          45          46          47          48
RUN PT.
15    1    -0.001802 -0.001785 -0.001813 -0.001813 -0.000001  0.000000
15    2    -0.001817 -0.001797 -0.001809 -0.001809  0.000000  0.000000
15    3    -0.001818 -0.001802 -0.001803 -0.001804 -0.000001  0.000000
15    4    -0.001818 -0.001813 -0.001808 -0.001807  0.000000  0.000000
15    5    -0.001818 -0.001810 -0.001808 -0.001807  0.000000  0.000000
15    6    -0.001818 -0.001814 -0.001807 -0.001806 -0.000001 -0.000001
15    7    -0.001810 -0.001807 -0.001805 -0.001805 -0.000001 -0.000001
15    8    -0.001808 -0.001803 -0.001804 -0.001805  0.000000  0.000000

CHANNEL      0          1          2          3          4           RPM
RUN PT
15    1   0.006500   0.006012   0.005292   0.004331   0.005230     12081
15    2   0.006550   0.006080   0.005361   0.004401   0.005305     13081
15    3   0.006573   0.006113   0.005397   0.004459   0.005347     13982
15    4   0.006601   0.006138   0.005425   0.004510   0.005376     14981
15    5   0.006627   0.006179   0.005458   0.004597   0.005405     16089
15    6   0.006633   0.006186   0.005480   0.004639   0.005425     17025
15    7   0.006632   0.006196   0.005496   0.004664   0.005435     19047
15    8   0.006607   0.006183   0.005505   0.004686   0.005437     19940

CHANNEL      5          6          20         21         23          RPM
RUN PT
15    1   0.001189   0.003358  -0.001103   0.000655   0.004400     12081
15    2   0.001067   0.003418  -0.000980   0.000796   0.004238     13081
15    3   0.000931   0.003496  -0.000869   0.000932   0.004120     13982
15    4   0.000882   0.003484  -0.000750   0.001112   0.003957     14981
15    5   0.000825   0.003399  -0.000572   0.001292   0.003848     16089
15    6   0.000637   0.003619  -0.000402   0.001312   0.003723     17025
15    7   0.000639   0.003878  -0.000075   0.001753   0.003397     19047
15    8   0.000624   0.003893   0.000080   0.001983   0.003247     19940

CHANNEL      23         24         25         26         27          RPM
RUN PT
15    1   0.004400   0.003595   0.002995   0.007763   0.002104     12081
15    2   0.004238   0.003549   0.002994   0.007748   0.002218     13081
15    3   0.004120   0.003515   0.002995   0.007755   0.044709     13982
15    4   0.003957   0.003468   0.002995   0.007743   0.044690     14981
15    5   0.003848   0.003445   0.002995   0.007777   0.044705     16089
15    6   0.003723   0.003400   0.002994   0.007775   0.044691     17025
15    7   0.003397   0.003283   0.002995   0.007757   0.044668     19047
15    8   0.003247   0.003223   0.002994   0.007756   0.044663     19940
```

## TABLE XXIII
## RUN 10 REDUCED DATA

VELOCITY TRIANGLE

| T. | V1 | V2 | VA1 | VA2 | VU1 | VU2 |
|---|---|---|---|---|---|---|
| 1 | 1555.2 | 435.8 | 398.8 | 256.9 | 1503.2 | -352.0 |
| 2 | 1540.5 | 406.8 | 397.7 | 257.1 | 1488.3 | -315.2 |
| 3 | 1522.5 | 376.1 | 381.7 | 253.2 | 1473.9 | -278.1 |
| 4 | 1501.2 | 337.0 | 382.5 | 254.9 | 1451.7 | -220.4 |
| 5 | 1482.3 | 305.7 | 374.3 | 252.7 | 1434.3 | -171.9 |
| 6 | 1457.8 | 285.2 | 364.1 | 251.4 | 1411.6 | -134.6 |
| 7 | 1436.0 | 270.9 | 356.4 | 250.4 | 1391.1 | -103.3 |
| 8 | 1394.9 | 255.2 | 311.4 | 252.0 | 1359.7 | -40.2 |
| 9 | 1401.8 | 263.0 | 378.4 | 262.5 | 1349.8 | -16.0 |

| | MACH NUMBERS | | | | ANGLES | | | |
|---|---|---|---|---|---|---|---|---|
| T. | M1 | MA1 | M2 | MA2 | A1 | A2 | B1 | B2 |
| 1 | 1.521 | 0.390 | 0.357 | 0.210 | 75.1 | -53.9 | 70.0 | -71.4 |
| 2 | 1.501 | 0.388 | 0.333 | 0.210 | 75.0 | -50.8 | 69.2 | -71.4 |
| 3 | 1.475 | 0.370 | 0.307 | 0.207 | 75.5 | -47.7 | 69.0 | -71.7 |
| 4 | 1.447 | 0.369 | 0.275 | 0.208 | 75.2 | -40.8 | 67.8 | -71.1 |
| 5 | 1.423 | 0.359 | 0.249 | 0.206 | 75.4 | -34.2 | 67.1 | -70.9 |
| 6 | 1.390 | 0.347 | 0.232 | 0.205 | 75.5 | -28.2 | 66.2 | -71.0 |
| 7 | 1.362 | 0.338 | 0.220 | 0.204 | 75.6 | -22.4 | 65.2 | -71.1 |
| 8 | 1.309 | 0.292 | 0.208 | 0.205 | 77.1 | -9.1 | 65.7 | -70.8 |
| 9 | 1.318 | 0.356 | 0.214 | 0.214 | 74.3 | -3.5 | 59.5 | -70.3 |

LOSSES

| T. | ZS | ZSTH | ZR | ZRTH | ZR* | ZI | Y |
|---|---|---|---|---|---|---|---|
| 1 | 0.0522 | 0.1048 | 0.4167 | 0.3315 | 0.4107 | 2.0E-02 | -0.087 |
| 2 | 0.0643 | 0.1042 | 0.3751 | 0.3261 | 0.3730 | 1.6E-02 | -0.061 |
| 3 | 0.0565 | 0.1047 | 0.3464 | 0.3217 | 0.3439 | 1.5E-02 | -0.086 |
| 4 | 0.0785 | 0.1040 | 0.3211 | 0.3195 | 0.3227 | 1.0E-02 | -0.037 |
| 5 | 0.0832 | 0.1038 | 0.2972 | 0.3156 | 0.2990 | 7.8E-03 | -0.030 |
| 6 | 0.0898 | 0.1037 | 0.2622 | 0.3094 | 0.2603 | 5.4E-03 | -0.020 |
| 7 | 0.0966 | 0.1034 | 0.2253 | 0.3024 | 0.2179 | 3.2E-03 | -0.007 |
| 8 | 0.0462 | 0.1052 | 0.3379 | 0.3052 | 0.2973 | 4.1E-03 | -0.170 |
| 9 | 0.1633 | 0.1008 | 0.0479 | 0.2739 | 0.0285 | 1.8E-03 | 0.190 |

## RUN 10 REDUCED DATA

| T. | P.R. | STPR | H.P. | RTM | STM | AXF | CLF |
|---|---|---|---|---|---|---|---|
| 1 | 3.46 | 4.12 | 78.54 | 446.90 | 361.02 | -121.87 | 5.90 |
| 2 | 3.50 | 4.08 | 83.39 | 435.93 | 358.74 | -106.20 | 7.24 |
| 3 | 3.48 | 3.87 | 87.64 | 422.01 | 354.13 | -90.88 | 8.62 |
| 4 | 3.52 | 3.84 | 90.08 | 403.29 | 349.41 | -76.94 | 10.25 |
| 5 | 3.51 | 3.73 | 92.44 | 387.10 | 345.07 | -63.33 | 12.40 |
| 6 | 3.51 | 3.58 | 94.85 | 372.60 | 339.71 | -46.48 | 12.57 |
| 7 | 3.51 | 3.46 | 96.83 | 360.36 | 335.08 | -29.20 | 13.49 |
| 8 | 3.51 | 2.96 | 98.35 | 337.17 | 327.34 | -3.52 | 16.57 |
| 9 | 3.64 | 3.61 | 102.53 | 334.04 | 330.06 | 23.17 | 18.73 |

```
T.    MW-DOT       PTO      TTO       PHD       P-TIP       P1        P-HUB
 1     1.84697   59.622   636.4     17.235    17.253     14.471     12.094
 2     1.85365   59.907   635.9     17.110    17.848     14.671     12.506
 3     1.84776   59.570   636.0     17.124    18.523     15.404     12.983
 4     1.85100   59.838   635.5     17.016    19.179     15.569     13.404
 5     1.85015   59.790   634.6     17.023    19.800     16.036     13.904
 6     1.85066   59.789   634.6     17.018    20.544     16.706     14.392
 7     1.85237   59.763   634.2     17.011    21.204     17.266     14.936
 8     1.85136   59.765   634.2     17.007    22.167     20.162     15.286
 9     1.88051   60.717   634.4     16.697    22.734     16.806     16.903
  ---------------------------------------------------------
T.    PTIP/PTO    P1/PTO    PHUB/PTO     KIS      TURB RE     DEL T      ETA
 1      0.289      0.243      0.203     13.614    2280990     119.57    0.655
 2      0.298      0.245      0.209     11.585    2336330     130.72    0.687
 3      0.311      0.259      0.218      9.785    2287810     136.93    0.728
 4      0.321      0.260      0.224      8.525    2373860     140.52    0.741
 5      0.331      0.268      0.233      7.434    2384580     142.20    0.763
 6      0.344      0.279      0.241      6.544    2397370     145.35    0.783
 7      0.355      0.289      0.250      5.871    2414040     148.90    0.799
 8      0.371      0.337      0.256      5.018    2221090     146.46    0.806
 9      0.374      0.277      0.278      4.678    2717720     151.29    0.801
  --------------------------------------------------------
T.    DELTA    THETA    RHP       RMW-DOT     RRTM       RSTM        RN
 1    1.993    1.227    35.584    1.02664    224.267    181.167    10000
 2    2.002    1.226    37.618    1.02503    217.722    179.171    10889
 3    1.991    1.226    39.752    1.02766    211.960    177.868    11820
 4    2.000    1.225    40.693    1.02446    201.651    174.711    12718
 5    1.998    1.223    41.824    1.02408    193.711    172.682    13608
 6    1.998    1.223    42.916    1.02434    186.460    169.998    14506
 7    1.997    1.223    43.843    1.02544    180.414    167.757    15316
 8    1.997    1.223    44.529    1.02482    168.794    163.873    16626
 9    2.029    1.223    45.688    1.02482    164.605    162.646    17493
  ---------------------------------------------------------
T.    RTH     REFF       RAF        RPM
 1   -0.11   -1.12     130.79     11077
 2   -0.09   -0.95     132.31     12057
 3   -0.07   -0.77     136.78     13089
 4   -0.05   -0.68     138.09     14078
 5   -0.03   -0.56     141.09     15051
 6   -0.01   -0.39     145.51     16045
 7    0.01   -0.23     149.26     16935
 8    0.13   -0.00     168.25     18384
 9    0.02    0.06     147.43     19346
---------------------------------------------------------


                     NOZZLE PRESSURE RATIOS
T.     P1       P2       P3       P4       P5       P6       P7
 1    0.204    0.441    0.251    0.283    0.213    0.197    0.661
 2    0.210    0.441    0.251    0.283    0.223    0.202    0.661
 3    0.219    0.441    0.251    0.283    0.243    0.209    0.661
 4    0.225    0.441    0.251    0.283    0.262    0.215    0.661
 5    0.232    0.441    0.251    0.283    0.284    0.221    0.662
 6    0.241    0.441    0.251    0.283    0.313    0.229    0.662
 7    0.251    0.441    0.251    0.283    0.322    0.237    0.662
 8    0.256    0.441    0.251    0.284    0.331    0.243    0.663
 9    0.277    0.441    0.251    0.284    0.349    0.255    0.663
  ---------------------------------------------------------
'T.    P8       P9
 1    0.497    0.203
 2    0.495    0.204
 3    0.496    0.205
 4    0.495    0.205
 5    0.494    0.206
 6    0.494    0.207
 7    0.494    0.209
 8    0.494    0.210
 9    0.492    0.212
```

## TABLE XXIV

### RUN 11 REDUCED DATA

#### VELOCITY TRIANGLE

| T. | V1 | V2 | VA1 | VA2 | VU1 | VU2 |
|---|---|---|---|---|---|---|
| 1 | 1558.4 | 438.2 | 403.4 | 259.2 | 1505.3 | -353.3 |
| 2 | 1543.7 | 405.1 | 410.5 | 258.8 | 1488.1 | -311.7 |
| 3 | 1516.1 | 370.6 | 387.4 | 253.3 | 1465.8 | -270.6 |
| 4 | 1500.6 | 343.7 | 382.9 | 254.2 | 1450.9 | -231.3 |
| 5 | 1481.5 | 313.5 | 382.1 | 255.8 | 1431.4 | -181.3 |
| 6 | 1460.7 | 295.1 | 369.9 | 252.2 | 1413.1 | -153.3 |
| 7 | 1435.1 | 273.5 | 366.0 | 253.1 | 1387.7 | -103.7 |
| 8 | 1407.3 | 258.5 | 341.8 | 253.0 | 1365.2 | -53.2 |

| | MACH NUMBERS | | | | ANGLES | | | |
|---|---|---|---|---|---|---|---|---|
| T. | M1 | MA1 | M2 | MA2 | A1 | A2 | B1 | B2 |
| 1 | 1.517 | 0.393 | 0.358 | 0.211 | 75.0 | -53.7 | 69.8 | -71.3 |
| 2 | 1.497 | 0.398 | 0.330 | 0.211 | 74.6 | -50.3 | 68.5 | -71.3 |
| 3 | 1.459 | 0.373 | 0.301 | 0.206 | 75.2 | -46.9 | 68.6 | -71.5 |
| 4 | 1.439 | 0.367 | 0.279 | 0.207 | 75.2 | -42.3 | 67.8 | -71.3 |
| 5 | 1.415 | 0.365 | 0.255 | 0.208 | 75.1 | -35.3 | 66.6 | -70.9 |
| 6 | 1.387 | 0.351 | 0.240 | 0.205 | 75.3 | -31.3 | 66.1 | -71.2 |
| 7 | 1.354 | 0.345 | 0.222 | 0.205 | 75.2 | -22.3 | 64.6 | -70.9 |
| 8 | 1.319 | 0.320 | 0.210 | 0.205 | 75.9 | -11.9 | 64.2 | -70.7 |

#### LOSSES

| T. | ZS | ZSTH | ZR | ZRTH | ZR* | ZI | Y |
|---|---|---|---|---|---|---|---|
| 1 | 0.0583 | 0.1002 | 0.4112 | 0.3165 | 0.4060 | 1.9E-02 | -0.063 |
| 2 | 0.0824 | 0.0993 | 0.3498 | 0.3095 | 0.3519 | 1.3E-02 | -0.005 |
| 3 | 0.0746 | 0.0999 | 0.3313 | 0.3074 | 0.3316 | 1.3E-02 | -0.028 |
| 4 | 0.0815 | 0.0996 | 0.3057 | 0.3038 | 0.3074 | 1.0E-02 | -0.014 |
| 5 | 0.0983 | 0.0989 | 0.2762 | 0.3000 | 0.2800 | 6.5E-03 | 0.027 |
| 6 | 0.0987 | 0.0991 | 0.2408 | 0.2946 | 0.2413 | 5.1E-03 | 0.021 |
| 7 | 0.1159 | 0.0985 | 0.2063 | 0.2886 | 0.2034 | 2.1E-03 | 0.063 |
| 8 | 0.0994 | 0.0991 | 0.2480 | 0.2861 | 0.2242 | 1.5E-03 | 0.006 |

### RUN 11 REDUCED DATA

| T. | P.R. | STPR | H.P. | RTM | STM | AXF | CLF |
|---|---|---|---|---|---|---|---|
| 1 | 3.47 | 4.14 | 98.62 | 558.49 | 450.97 | -152.27 | 7.30 |
| 2 | 3.50 | 4.20 | 104.40 | 541.32 | 446.35 | -134.82 | 8.83 |
| 3 | 3.44 | 3.89 | 107.81 | 517.78 | 436.01 | -118.28 | 10.99 |
| 4 | 3.47 | 3.82 | 112.28 | 504.49 | 434.17 | -98.79 | 12.73 |
| 5 | 3.51 | 3.78 | 115.51 | 485.32 | 429.99 | -80.22 | 15.56 |
| 6 | 3.48 | 3.62 | 117.92 | 469.52 | 422.90 | -65.45 | 17.34 |
| 7 | 3.49 | 3.53 | 119.70 | 447.39 | 415.82 | -39.11 | 17.64 |
| 8 | 3.49 | 3.25 | 121.83 | 426.18 | 409.95 | -8.25 | 20.10 |

```
PT.    MW-DOT       PTO      TTO        PHD       P-TIP       P1        P-HUB
  1    2.30389    74.610    641.0     21.512     21.543    18.001    15.091
  2    2.30660    74.951    641.0     21.440     22.321    17.861    15.732
  3    2.28750    74.151    640.6     21.578     23.258    19.055    16.363
  4    2.30123    74.517    639.6     21.458     24.072    19.516    16.890
  5    2.31013    74.890    639.1     21.339     24.853    19.819    17.463
  6    2.30148    74.566    639.0     21.447     25.669    20.617    18.071
  7    2.30438    74.611    638.6     21.397     26.644    21.128    18.896
  8    2.30926    74.639    638.6     21.408     27.656    22.987    19.731
    ---------------------------------------------------------------------------
PT.   PTIP/PTO    P1/PTO    PHUB/PTO     KIS      TURB RE     DEL T      ETA
  1     0.289      0.241     0.202     13.625    2861040    121.63    0.653
  2     0.298      0.238     0.210     11.511    2988360    129.66    0.685
  3     0.314      0.257     0.221      9.763    2902260    136.83    0.721
  4     0.323      0.262     0.227      8.597    2948990    139.92    0.742
  5     0.332      0.265     0.233      7.572    3036640    141.09    0.755
  6     0.344      0.276     0.242      6.760    3009450    142.42    0.778
  7     0.357      0.283     0.253      5.976    3080720    148.05    0.786
  8     0.371      0.308     0.264      5.240    2980230    146.30    0.798
    ---------------------------------------------------------------------------
PT.    DELTA    THETA     RHP       RMW-DOT      RRTM       RSTM         RN
  1    2.494    1.236    35.576    1.02707    223.965    180.848     10011
  2    2.505    1.236    37.491    1.02358    216.092    178.180     10935
  3    2.478    1.235    39.143    1.02576    208.923    175.930     11808
  4    2.491    1.233    40.598    1.02602    202.561    174.326     12632
  5    2.503    1.232    41.574    1.02445    193.894    171.786     13514
  6    2.492    1.232    42.630    1.02499    188.396    169.692     14261
  7    2.494    1.231    43.259    1.02536    179.410    166.748     15197
  8    2.495    1.231    44.016    1.02712    170.838    164.332     16238
    ---------------------------------------------------------------------------
PT.   ·RTH     REFF       RAF        RPM
  1   -0.11   -1.10     163.11     11129
  2   -0.11   -0.95     162.61     12155
  3   -0.07   -0.77     169.62     13123
  4   -0.05   -0.65     172.91     14027
  5   -0.04   -0.54     175.21     15000
  6   -0.02   -0.38     180.19     15829
  7    0.00   -0.25     183.74     16862
  8    0.06   -0.08     195.93     18017
---------------------------------------------------------------------------


                             NOZZLE PRESSURE RATIOS
PT.
       P1       P2        P3        P4        P5        P6        P7
  1   0.203    0.441    0.250     0.281     0.222     0.196     0.655
  2   0.210    0.440    0.250     0.281     0.238     0.203     0.655
  3   0.221    0.441    0.250     0.281     0.266     0.212     0.656
  4   0.228    0.441    0.250     0.281     0.284     0.217     0.656
  5   0.234    0.441    0.250     0.281     0.300     0.221     0.656
  6   0.243    0.441    0.251     0.282     0.327     0.230     0.657
  7   0.253    0.441    0.250     0.282     0.335     0.239     0.658
  8   0.263    0.441    0.251     0.283     0.345     0.248     0.659
    ---------------------------------------------------------------------------
PT.
       P8       P9
  1   0.488    0.206
  2   0.487    0.206
  3   0.489    0.209
  4   0.487    0.210
  5   0.486    0.211
  6   0.486    0.211
  7   0.487    0.212
  8   0.486    0.214
```

# TABLE XXV

## RUN 12 REDUCED DATA

### VELOCITY TRIANGLE

| PT. | V1 | V2 | VA1 | VA2 | VU1 | VU2 |
|---|---|---|---|---|---|---|
| 1 | 1438.8 | 369.6 | 361.2 | 240.8 | 1392.8 | -280.4 |
| 2 | 1402.5 | 308.4 | 347.4 | 238.0 | 1358.8 | -196.1 |
| 3 | 1341.9 | 260.2 | 319.3 | 238.4 | 1303.3 | -104.1 |
| 4 | 1306.9 | 244.6 | 298.1 | 239.7 | 1272.4 | -48.8 |
| 5 | 1286.2 | 242.2 | 304.3 | 242.0 | 1249.7 | 9.6 |
| 6 | 1266.0 | 238.3 | 288.7 | 238.2 | 1232.6 | 5.8 |

|  | MACH NUMBERS |  |  |  | ANGLES |  |  |  |
|---|---|---|---|---|---|---|---|---|
| PT. | M1 | MA1 | M2 | MA2 | A1 | A2 | B1 | B2 |
| 1 | 1.464 | 0.368 | 0.318 | 0.207 | 75.5 | -49.3 | 69.1 | -71.8 |
| 2 | 1.415 | 0.350 | 0.265 | 0.204 | 75.7 | -39.5 | 67.9 | -71.4 |
| 3 | 1.332 | 0.317 | 0.223 | 0.204 | 76.2 | -23.6 | 66.1 | -71.1 |
| 4 | 1.286 | 0.293 | 0.210 | 0.205 | 76.8 | -11.5 | 65.5 | -70.5 |
| 5 | 1.260 | 0.298 | 0.208 | 0.207 | 76.3 | 2.3 | 63.2 | -69.5 |
| 6 | 1.235 | 0.282 | 0.204 | 0.204 | 76.8 | 1.4 | 61.7 | -71.2 |

### LOSSES

| PT. | ZS | ZSTH | ZR | ZRTH | ZR* | ZI | Y |
|---|---|---|---|---|---|---|---|
| 1 | 0.0672 | 0.0975 | 0.3403 | 0.3125 | 0.3365 | 1.5E-02 | -0.034 |
| 2 | 0.0787 | 0.0974 | 0.3061 | 0.3079 | 0.3032 | 1.0E-02 | -0.018 |
| 3 | 0.0869 | 0.0972 | 0.2847 | 0.2988 | 0.2643 | 5.0E-03 | -0.018 |
| 4 | 0.0766 | 0.0973 | 0.3427 | 0.2994 | 0.3060 | 3.7E-03 | -0.064 |
| 5 | 0.1116 | 0.0966 | 0.3338 | 0.2934 | 0.2924 | 4.1E-04 | 0.029 |
| 6 | 0.0953 | 0.0971 | 0.2546 | 0.2728 | 0.1812 | 1.9E-05 | -0.024 |

## RUN 12 REDUCED DATA

| PT. | P.R. | STPR | H.P. | RTM | STM | AXF | CLF |
|---|---|---|---|---|---|---|---|
| 1 | 3.52 | 3.87 | 81.85 | 422.33 | 350.63 | -73.19 | 8.77 |
| 2 | 3.50 | 3.65 | 85.83 | 391.52 | 341.46 | -46.88 | 11.87 |
| 3 | 3.51 | 3.25 | 90.24 | 355.41 | 328.73 | 6.87 | 15.45 |
| 4 | 3.52 | 2.99 | 89.68 | 333.20 | 320.71 | 27.69 | 18.08 |
| 5 | 3.52 | 3.02 | 88.08 | 312.68 | 315.13 | 46.68 | 20.26 |
| 6 | 3.51 | 2.83 | 93.34 | 308.88 | 310.36 | 72.73 | 22.55 |

| PT. | MW-DOT | PTO | TTO | PHD | P-TIP | P1 | P-HUB |
|---|---|---|---|---|---|---|---|
| 1 | 1.93601 | 59.889 | 574.1 | 17.014 | 19.087 | 15.467 | 13.506 |
| 2 | 1.93250 | 59.688 | 572.5 | 17.033 | 20.298 | 16.333 | 14.437 |
| 3 | 1.93971 | 59.875 | 571.9 | 17.036 | 22.230 | 18.410 | 16.191 |
| 4 | 1.93832 | 59.891 | 571.5 | 17.012 | 23.022 | 20.051 | 16.622 |
| 5 | 1.93916 | 59.834 | 571.3 | 17.018 | 23.573 | 19.844 | 17.555 |
| 6 | 1.93629 | 59.730 | 570.9 | 17.025 | 24.296 | 21.073 | 18.356 |

```
PT.    PTIP/PTO    P1/PTO    PHUB/PTO     KIS      TURB RE     DEL T     ETA
 1       0.319      0.258      0.226     10.200    2632900      97.80    0.715
 2       0.340      0.274      0.242      7.933    2665570     101.53    0.755
 3       0.371      0.307      0.270      5.954    2673260     103.20    0.785
 4       0.384      0.335      0.278      5.308    2612530     104.14    0.779
 5       0.394      0.332      0.293      4.853    2734740     106.19    0.764
 6       0.407      0.353      0.307      4.224    2656200     107.72    0.809
   ------------------------------------------------------------
PT.    DELTA    THETA    RHP       RMW-DOT      RRTM        RSTM          RN
 1     2.002    1.107    38.866    1.01757     210.994     175.170      11610
 2     1.995    1.104    40.954    1.01772     196.257     171.164      13152
 3     2.001    1.103    42.946    1.01778     177.601     164.269      15240
 4     2.002    1.102    42.683    1.01646     166.459     160.220      16161
 5     2.000    1.101    41.970    1.01765     156.354     157.581      16918
 6     1.996    1.101    44.568    1.01758     154.726     155.467      18154
   -------------------------------------------------------------
PT.    RTH      REFF       RAF         RPM
 1    -0.06    -0.73     137.06      12214
 2    -0.02    -0.54     142.65      13817
 3     0.06    -0.16     156.52      16003
 4     0.12    -0.02     167.47      16964
 5     0.12     0.02     166.30      17755
 6     0.16     0.29     174.50      19046
-------------------------------------------------------------


                       NOZZLE PRESSURE RATIOS
PT.       P1        P2        P3        P4        P5        P6        P7
 1     0.226     0.440     0.262     0.308     0.254     0.216     0.664
 2     0.243     0.441     0.262     0.307     0.279     0.231     0.664
 3     0.269     0.441     0.262     0.308     0.335     0.255     0.664
 4     0.280     0.441     0.262     0.310     0.349     0.262     0.664
 5     0.296     0.442     0.261     0.309     0.374     0.275     0.665
 6     0.306     0.441     0.261     0.310     0.397     0.284     0.665
   -------------------------------------------------------------
PT.       P8        P9
 1     0.495     0.233
 2     0.494     0.233
 3     0.494     0.235
 4     0.285     0.236
 5     0.284     0.237
 6     0.285     0.238
```

## TABLE XXVI

### RUN 13 REDUCED DATA

VELOCITY TRIANGLE

| PT. | V1 | V2 | VA1 | VA2 | VU1 | VU2 |
|---|---|---|---|---|---|---|
| 1 | 1426.6 | 357.6 | 375.7 | 241.1 | 1376.3 | -264.1 |
| 2 | 1407.7 | 335.5 | 357.1 | 239.7 | 1361.6 | -234.7 |
| 3 | 1390.9 | 304.3 | 347.4 | 240.0 | 1346.8 | -187.0 |
| 4 | 1370.3 | 277.2 | 341.4 | 238.4 | 1327.1 | -141.4 |
| 5 | 1324.9 | 260.2 | 322.5 | 238.6 | 1285.0 | -103.9 |
| 6 | 1307.4 | 247.9 | 319.7 | 240.0 | 1267.7 | -62.3 |
| 7 | 1250.5 | 242.6 | 307.3 | 242.6 | 1212.1 | -3.9 |
| 8 | 1230.0 | 248.7 | 298.6 | 243.5 | 1193.2 | 50.7 |

|  | MACH NUMBERS |  |  |  | ANGLES |  |  |  |
|---|---|---|---|---|---|---|---|---|
| PT. | M1 | MA1 | M2 | MA2 | A1 | A2 | B1 | B2 |
| 1 | 1.446 | 0.381 | 0.307 | 0.207 | 74.7 | -47.6 | 68.1 | -71.3 |
| 2 | 1.422 | 0.361 | 0.288 | 0.206 | 75.3 | -44.4 | 68.0 | -71.6 |
| 3 | 1.398 | 0.349 | 0.261 | 0.206 | 75.5 | -37.9 | 67.4 | -71.3 |
| 4 | 1.369 | 0.341 | 0.238 | 0.204 | 75.6 | -30.7 | 66.4 | -71.1 |
| 5 | 1.308 | 0.318 | 0.223 | 0.204 | 75.9 | -23.5 | 65.2 | -71.2 |
| 6 | 1.284 | 0.314 | 0.212 | 0.205 | 75.8 | -14.5 | 63.7 | -70.9 |
| 7 | 1.210 | 0.298 | 0.207 | 0.207 | 75.8 | -0.9 | 59.4 | -71.1 |
| 8 | 1.185 | 0.288 | 0.213 | 0.208 | 76.0 | 11.8 | 57.2 | -70.6 |

LOSSES

| PT. | ZS | ZSTH | ZR | ZRTH | ZR* | ZI | Y |
|---|---|---|---|---|---|---|---|
| 1 | 0.0995 | 0.0955 | 0.3204 | 0.3124 | 0.3234 | 1.1E-02 | 0.029 |
| 2 | 0.0878 | 0.0973 | 0.3001 | 0.3081 | 0.2992 | 1.1E-02 | 0.004 |
| 3 | 0.0876 | 0.0971 | 0.2929 | 0.3059 | 0.2895 | 8.7E-03 | -0.003 |
| 4 | 0.0969 | 0.0970 | 0.2646 | 0.3013 | 0.2598 | 5.8E-03 | 0.015 |
| 5 | 0.1073 | 0.0953 | 0.2533 | 0.2952 | 0.2330 | 3.2E-03 | 0.013 |
| 6 | 0.1199 | 0.0957 | 0.2281 | 0.2874 | 0.1981 | 8.4E-04 | 0.052 |
| 7 | 0.1536 | 0.0956 | 0.1707 | 0.2636 | 0.0970 | 2.0E-03 | 0.136 |
| 8 | 0.1563 | 0.0942 | 0.2030 | 0.2535 | 0.1043 | 7.1E-03 | 0.125 |

### RUN 13 REDUCED DATA

| PT. | P.R. | STPR | H.P. | RTM | STM | AXF | CLF |
|---|---|---|---|---|---|---|---|
| 1 | 3.55 | 3.99 | 79.95 | 416.97 | 348.95 | -69.55 | 10.30 |
| 2 | 3.51 | 3.75 | 84.17 | 405.51 | 345.09 | -60.62 | 10.13 |
| 3 | 3.53 | 3.61 | 87.13 | 390.31 | 342.06 | -40.45 | 12.26 |
| 4 | 3.52 | 3.50 | 88.76 | 373.07 | 336.63 | -23.08 | 14.09 |
| 5 | 3.52 | 3.23 | 89.69 | 352.33 | 325.59 | 7.73 | 15.91 |
| 6 | 3.53 | 3.17 | 91.25 | 337.65 | 321.60 | 30.28 | 18.52 |
| 7 | 3.54 | 2.97 | 92.76 | 308.45 | 307.44 | 64.01 | 22.53 |
| 8 | 3.54 | 2.85 | 91.87 | 289.39 | 302.45 | 86.35 | 24.10 |

```
    ------------------------------------------------------------------------
PT.    MW-DOT       PTO       TTO        PHD        P-TIP        P1        P-HUB
  1    1.94983    60.216    574.3     16.950     19.185     15.093     13.625
  2    1.94901    60.001    572.8     17.118     19.841     15.986     14.014
  3    1.95315    60.059    572.9     17.006     20.479     16.633     14.572
  4    1.95062    59.909    573.1     17.013     21.251     17.105     15.196
  5    1.94853    59.851    573.3     17.006     22.275     18.536     16.102
  6    1.95096    59.952    573.4     16.967     22.987     18.892     16.967
  7    1.95055    60.010    574.2     16.949     24.114     20.238     18.082
  8    1.94933    60.034    574.5     16.959     24.792     21.030     18.827
    ------------------------------------------------------------------------
PT.    PTIP/PTO    P1/PTO    PHUB/PTO     KIS       TURB RE      DEL T      ETA
  1      0.319      0.251      0.226     10.351     2802710      90.46     0.698
  2      0.331      0.266      0.234      8.846     2733700      99.88     0.734
  3      0.341      0.277      0.243      7.676     2725040      96.57     0.755
  4      0.355      0.286      0.254      6.738     2747380      96.23     0.773
  5      0.372      0.310      0.269      5.896     2752930      97.27     0.780
  6      0.383      0.315      0.283      5.266     2794900      96.72     0.788
  7      0.402      0.337      0.301      4.301     2876900      96.27     0.792
  8      0.413      0.350      0.314      3.865     2861270      98.72     0.784
    -----------------------------------------------------------------------
PT.    DELTA     THETA     RHP        RMW-DOT      RRTM         RSTM          RN
  1    2.013     1.107    37.755     1.01942     207.184      173.383       11485
  2    2.005     1.104    39.941     1.02128     202.212      172.080       12449
  3    2.007     1.104    41.305     1.02258     194.445      170.405       13388
  4    2.002     1.105    42.172     1.02399     186.319      168.118       14265
  5    2.000     1.105    42.649     1.02403     176.129      162.765       15261
  6    2.004     1.105    43.312     1.02368     168.507      160.497       16200
  7    2.006     1.107    43.955     1.02320     .153.787     153.283       18014
  8    2.006     1.107    43.509     1.02239      144.228     150.736       19013
    ------------------------------------------------------------------------
PT.    RTH      REFF       RAF         RPM
  1   -0.09    -0.81     135.30      12085
  2   -0.04    -0.59     140.83      13081
  3   -0.01    -0.47     145.11      14070
  4    0.00    -0.35     148.23      14995
  5    0.06    -0.11     157.74      16044
  6    0.08     0.01     160.25      17032
  7    0.13     0.32     169.54      18953
  8    0.16     0.40     174.90      20009
-------------------------------------------------------------------------


                          NOZZLE PRESSURE RATIOS
PT.      P1        P2        P3        P4        P5        P6        P7
  1    0.227     0.440     0.261     0.313     0.262     0.217     0.664
  2    0.234     0.441     0.258     0.305     0.269     0.224     0.666
  3    0.243     0.441     0.259     0.306     0.290     0.231     0.666
  4    0.254     0.441     0.259     0.306     0.316     0.240     0.667
  5    0.269     0.441     0.262     0.316     0.337     0.254     0.667
  6    0.283     0.442     0.261     0.312     0.356     0.264     0.667
  7    0.301     0.441     0.259     0.309     0.389     0.278     0.667
  8    0.312     0.440     0.261     0.319     0.427     0.290     0.665
    -------------------------------------------------------------------------
PT.      P8        P9
  1    0.282     0.232
  2    0.286     0.230
  3    0.284     0.231
  4    0.284     0.232
  5    0.284     0.236
  6    0.283     0.237
  7 ,  0.282     0.237
  8    0.282     0.243
```

# TABLE XXVII

## RUN 14 REDUCED DATA

### VELOCITY TRIANGLE

| PT. | V1 | V2 | VA1 | VA2 | VU1 | VU2 |
|---|---|---|---|---|---|---|
| 1 | 1480.7 | 358.8 | 387.2 | 244.5 | 1429.1 | -262.6 |
| 2 | 1463.9 | 343.7 | 375.9 | 246.6 | 1414.8 | -239.3 |
| 3 | 1440.4 | 307.8 | 350.8 | 244.7 | 1397.0 | -186.7 |
| 4 | 1424.7 | 279.3 | 354.7 | 244.0 | 1379.8 | -135.8 |
| 5 | 1398.7 | 268.5 | 349.7 | 245.6 | 1354.3 | -108.4 |
| 6 | 1368.6 | 250.7 | 339.8 | 243.4 | 1325.8 | -60.2 |
| 7 | 1317.0 | 249.0 | 320.3 | 248.2 | 1277.4 | 19.4 |
| 8 | 1291.5 | 253.1 | 318.1 | 248.8 | 1251.8 | 46.2 |

| | MACH NUMBERS | | | | ANGLES | | | |
|---|---|---|---|---|---|---|---|---|
| PT. | M1 | MA1 | M2 | MA2 | A1 | A2 | B1 | B2 |
| 1 | 1.473 | 0.385 | 0.301 | 0.205 | 74.8 | -47.0 | 68.6 | -71.0 |
| 2 | 1.450 | 0.372 | 0.288 | 0.207 | 75.1 | -44.1 | 68.1 | -71.2 |
| 3 | 1.418 | 0.345 | 0.258 | 0.205 | 75.9 | -37.3 | 68.3 | -71.0 |
| 4 | 1.396 | 0.348 | 0.233 | 0.204 | 75.6 | -29.1 | 66.9 | -70.6 |
| 5 | 1.361 | 0.340 | 0.224 | 0.205 | 75.5 | -23.8 | 65.5 | -70.8 |
| 6 | 1.322 | 0.328 | 0.209 | 0.203 | 75.6 | -13.9 | 64.2 | -70.7 |
| 7 | 1.255 | 0.305 | 0.208 | 0.207 | 75.9 | 4.5 | 61.4 | -70.0 |
| 8 | 1.223 | 0.301 | 0.211 | 0.208 | 75.7 | 10.5 | 58.6 | -70.3 |

### LOSSES

| PT. | ZS | ZSTH | ZR | ZRTH | ZR* | ZI | Y |
|---|---|---|---|---|---|---|---|
| 1 | 0.0836 | 0.1011 | 0.3624 | 0.3219 | 0.3652 | 1.3E-02 | -0.001 |
| 2 | 0.0836 | 0.1008 | 0.3245 | 0.3157 | 0.3264 | 1.1E-02 | -0.007 |
| 3 | 0.0650 | 0.1017 | 0.3528 | 0.3176 | 0.3476 | 1.2E-02 | -0.065 |
| 4 | 0.0874 | 0.1012 | 0.3121 | 0.3124 | 0.3112 | 7.3E-03 | -0.011 |
| 5 | 0.1039 | 0.1003 | 0.2528 | 0.3024 | 0.2469 | 3.7E-03 | 0.026 |
| 6 | 0.1153 | 0.1004 | 0.2271 | 0.2959 | 0.2131 | 1.5E-03 | 0.051 |
| 7 | 0.1293 | 0.1001 | 0.2509 | 0.2835 | 0.2019 | 1.2E-04 | 0.075 |
| 8 | 0.1501 | 0.0989 | 0.1915 | 0.2661 | 0.1167 | 3.4E-03 | 0.139 |

## RUN 14 REDUCED DATA

| PT. | P.R. | STPR | H.P. | RTM | STM | AXF | CLF |
|---|---|---|---|---|---|---|---|
| 1 | 3.45 | 4.04 | 79.91 | 417.10 | 351.50 | -98.45 | 8.31 |
| 2 | 3.54 | 3.90 | 85.42 | 410.32 | 350.15 | -76.41 | 10.01 |
| 3 | 3.52 | 3.59 | 87.89 | 392.62 | 345.68 | -56.50 | 11.79 |
| 4 | 3.53 | 3.60 | 89.39 | 375.04 | 340.94 | -45.96 | 14.63 |
| 5 | 3.56 | 3.50 | 92.64 | 363.15 | 335.83 | -20.62 | 14.36 |
| 6 | 3.52 | 3.35 | 92.69 | 342.14 | 327.05 | -5.20 | 15.91 |
| 7 | 3.54 | 3.07 | 93.35 | 311.03 | 315.91 | 35.42 | 20.22 |
| 8 | 3.55 | 3.01 | 94.63 | 298.40 | 310.03 | 63.05 | 22.33 |

```
    ----------------------------------------------------------------------
PT.    MW-DOT         PTO       TTO          PHD        P-TIP        P1         P-HUB
  1     1.89142     59.668     603.1        17.284      18.409      14.757      13.040
  2     1.90319     60.123     602.2        17.002      19.075      15.411      13.427
  3     1.90295     60.009     602.2        17.053      19.855      16.732      14.001
  4     1.90022     60.001     602.0        17.017      20.507      16.663      14.473
  5     1.90703     60.203     602.0        16.896      21.276      17.198      15.146
  6     1.89705     59.846     602.0        17.017      21.950      17.886      15.789
  7     1.90177     59.999     602.5        16.970      23.276      19.531      17.073
  8     1.90469     60.063     602.5        16.929      24.090      19.939      18.062
    ----------------------------------------------------------------------
PT.    PTIP/PTO     P1/PTO     PHUB/PTO      KIS       TURB RE      DEL T       ETA
  1      0.309       0.247       0.219      10.741     2557360      117.52      0.694
  2      0.317       0.256       0.223       9.250     2565440      120.25      0.725
  3      0.331       0.279       0.233       7.969     2470460      121.01      0.749
  4      0.342       0.278       0.241       7.034     2552350      123.40      0.762
  5      0.353       0.286       0.252       6.202     2614610      124.63      0.780
  6      0.367       0.299       0.264       5.464     2625440      123.26      0.789
  7      0.388       0.326       0.285       4.514     2642310      123.76      0.782
  8      0.401       0.332       0.301       4.060     2705890      121.56      0.788
    ---------------------------------------------------------------------
PT.    DELTA     THETA     RHP          RMW-DOT       RRTM          RSTM            RN
  1    1.994     1.163    37.161        1.02273      209.150       176.255         11198
  2    2.009     1.161    39.450        1.02051      204.193       174.249         12177
  3    2.006     1.161    40.671        1.02228      195.755       172.354         13094
  4    2.005     1.161    41.378        1.02081      187.016       170.015         13945
  5    2.012     1.161    42.738        1.02100      180.479       166.903         14925
  6    2.000     1.161    43.016        1.02172      171.053       163.509         15849
  7    2.005     1.161    43.196        1.02208      155.104       157.536         17552
  8    2.007     1.162    43.739        1.02258      148.644       154.440         18545
    ----------------------------------------------------------------------
PT.    RTH      REFF        RAF          RPM
  1   -0.11    -1.01       132.80        12075
  2   -0.07    -0.74       137.14        13120
  3   -0.02    -0.61       145.50        14109
  4   -0.02    -0.53       145.19        15023
  5    0.01    -0.30       148.96        16078
  6    0.03    -0.15       153.39        17074
  7    0.10     0.12       164.56        18917
  8    0.12     0.28       167.50        19987
-------------------------------------------------------------------------


                           NOZZLE PRESSURE RATIOS
PT.       P1        P2        P3        P4        P5        P6        P7
  1     0.219     0.439     0.248     0.290     0.263     0.210     0.661
  2     0.224     0.439     0.248     0.291     0.272     0.214     0.661
  3     0.233     0.439     0.248     0.291     0.289     0.222     0.661
  4     0.243     0.439     0.248     0.290     0.312     0.228     0.661
  5     0.253     0.439     0.248     0.292     0.325     0.239     0.661
  6     0.263     0.439     0.248     0.291     0.341     0.248     0.662
  7     0.283     0.440     0.248     0.292     0.368     0.264     0.662
  8     0.301     0.440     0.248     0.296     0.411     0.280     0.663
     ----------------------------------------------------------------------
PT.       P8        P9
  1     0.498     0.216
  2     0.496     0.217
  3     0.495     0.217
  4     0.494     0.216
  5     0.489     0.219
  6     0.496     0.220
  7     0.492     0.222
  8     0.483     0.228
```

## TABLE XXVIII

### RUN 15 REDUCED DATA

VELOCITY TRIANGLE

| PT. | V1 | V2 | VA1 | VA2 | VU1 | VU2 |
|---|---|---|---|---|---|---|
| 1 | 1587.6 | 428.9 | 431.6 | 265.7 | 1527.8 | -336.7 |
| 2 | 1567.5 | 392.6 | 419.0 | 265.9 | 1510.4 | -288.9 |
| 3 | 1552.5 | 366.4 | 409.3 | 264.6 | 1497.6 | -253.5 |
| 4 | 1535.9 | 334.8 | 416.3 | 264.8 | 1478.4 | -204.8 |
| 5 | 1519.0 | 313.8 | 391.7 | 264.3 | 1467.6 | -169.1 |
| 6 | 1499.2 | 297.3 | 390.6 | 264.7 | 1447.5 | -135.3 |
| 7 | 1446.5 | 269.7 | 363.7 | 265.4 | 1400.1 | -47.9 |
| 8 | 1420.9 | 267.1 | 361.9 | 267.0 | 1374.1 | -9.9 |

| | MACH NUMBERS | | | | ANGLES | | | |
|---|---|---|---|---|---|---|---|---|
| PT. | M1 | MA1 | M2 | MA2 | A1 | A2 | B1 | B2 |
| 1 | 1.509 | 0.410 | 0.342 | 0.212 | 74.2 | -51.7 | 68.3 | -71.3 |
| 2 | 1.477 | 0.395 | 0.312 | 0.211 | 74.5 | -47.4 | 67.9 | -71.0 |
| 3 | 1.455 | 0.384 | 0.290 | 0.210 | 74.7 | -43.8 | 67.5 | -71.1 |
| 4 | 1.432 | 0.388 | 0.265 | 0.209 | 74.3 | -37.7 | 65.9 | -70.8 |
| 5 | 1.408 | 0.363 | 0.248 | 0.209 | 75.1 | -32.6 | 66.0 | -71.0 |
| 6 | 1.382 | 0.360 | 0.234 | 0.209 | 74.9 | -27.1 | 64.7 | -71.0 |
| 7 | 1.316 | 0.331 | 0.212 | 0.209 | 75.4 | -10.2 | 62.7 | -70.6 |
| 8 | 1.284 | 0.327 | 0.210 | 0.210 | 75.2 | -2.1 | 60.7 | -70.4 |

LOSSES

| PT. | ZS | ZSTH | ZR | ZRTH | ZR* | ZI | Y |
|---|---|---|---|---|---|---|---|
| 1 | 0.0886 | 0.1051 | 0.3417 | 0.3273 | 0.3457 | 1.2E-02 | 0.001 |
| 2 | 0.0917 | 0.1051 | 0.3282 | 0.3268 | 0.3331 | 1.1E-02 | 0.002 |
| 3 | 0.0923 | 0.1052 | 0.3017 | 0.3234 | 0.3073 | 9.1E-03 | -0.001 |
| 4 | 0.1161 | 0.1044 | 0.2360 | 0.3165 | 0.2507 | 4.7E-03 | 0.061 |
| 5 | 0.1001 | 0.1052 | 0.2454 | 0.3142 | 0.2488 | 4.9E-03 | 0.008 |
| 6 | 0.1162 | 0.1047 | 0.1890 | 0.3063 | 0.1920 | 2.2E-03 | 0.050 |
| 7 | 0.1212 | 0.1048 | 0.1884 | 0.2960 | 0.1631 | 1.5E-04 | 0.055 |
| 8 | 0.1414 | 0.1042 | 0.1555 | 0.2862 | 0.1164 | 4.8E-04 | 0.117 |

### RUN 15 REDUCED DATA

| PT. | P.R. | STPR | H.P. | RTM | STM | AXF | CLF |
|---|---|---|---|---|---|---|---|
| 1 | 3.59 | 4.33 | 84.34 | 440.01 | 359.52 | -110.33 | 6.55 |
| 2 | 3.57 | 4.14 | 87.97 | 423.85 | 354.90 | -97.97 | 7.96 |
| 3 | 3.57 | 3.99 | 91.40 | 411.99 | 351.54 | -86.85 | 9.32 |
| 4 | 3.58 | 4.02 | 94.05 | 395.66 | 346.84 | -75.02 | 11.12 |
| 5 | 3.60 | 3.75 | 98.24 | 384.81 | 344.48 | -57.21 | 12.92 |
| 6 | 3.62 | 3.70 | 100.57 | 372.29 | 340.00 | -40.21 | 13.12 |
| 7 | 3.59 | 3.34 | 102.66 | 339.69 | 328.28 | -7.50 | 17.53 |
| 8 | 3.58 | 3.28 | 102.72 | 324.66 | 322.30 | 8.00 | 19.83 |

```
 ---------------------------------------------------------------------------
PT.   MW-DOT       PTO       TTO        PHD       P-TIP       P1       P-HUB
  1   1.80965    60.115    670.5     16.751     17.233    13.875    12.037
  2   1.80692    60.027    673.0     16.794     17.824    14.508    12.469
  3   1.80513    59.932    674.3     16.802     18.367    15.006    12.837
  4   1.80417    59.909    675.3     16.730     18.980    14.909    13.281
  5   1.80507    60.119    676.3     16.694     19.659    16.026    13.715
  6   1.80638    60.146    676.9     16.632     20.337    16.268    14.219
  7   1.80318    59.899    677.2     16.703     21.662    17.912    15.364
  8   1.80378    59.878    677.3     16.722     22.264    18.230    16.016
 ---------------------------------------------------------------------------
PT.   PTIP/PTO    P1/PTO    PHUB/PTO      KIS      TURB RE     DEL T      ETA
  1     0.287     0.231      0.200      12.200    2301800    136.46    0.673
  2     0.297     0.242      0.208      10.466    2290550    143.17    0.699
  3     0.306     0.250      0.214       9.176    2276710    149.29    0.726
  4     0.317     0.249      0.222       8.026    2364690    151.96    0.745
  5     0.327     0.267      0.228       7.014    2280710    154.90    0.771
  6     0.338     0.270      0.236       6.293    2332180    162.16    0.785
  7     0.362     0.299      0.256       5.045    2306400    162.42    0.800
  8     0.372     0.304      0.267       4.618    2363560    163.01    0.798
 ---------------------------------------------------------------------------
PT.   DELTA    THETA    RHP       RMW-DOT       RRTM        RSTM          RN
  1   2.009    1.293   36.921    1.02403     218.998     178.939      10625
  2   2.006    1.297   38.494    1.02587     211.263     176.895      11484
  3   2.003    1.300   40.019    1.02753     205.680     175.498      12263
  4   2.002    1.302   41.166    1.02811     197.603     173.222      13130
  5   2.009    1.304   42.818    1.02575     191.513     171.443      14091
  6   2.010    1.305   43.793    1.02652     185.196     169.133      14903
  7   2.002    1.306   44.876    1.02918     169.676     163.977      16669
  8   2.001    1.306   44.916    1.02994     162.227     161.047      17450
 ---------------------------------------------------------------------------
PT.   RTH     REFF      RAF      RPM
  1  -0.13   -1.00    127.73    12081
  2  -0.10   -0.87    131.71    13081
  3  -0.08   -0.73    134.85    13982
  4  -0.08   -0.62    134.51    14981
  5  -0.03   -0.43    141.47    16089
  6  -0.01   -0.29    143.23    17025
  7   0.05   -0.01    153.94    19047
  8   0.07    0.11    156.22    19940
---------------------------------------------------------------------------


                      NOZZLE PRESSURE RATIOS
PT.     P1       P2       P3       P4       P5       P6       P7
  1   0.201    0.438    0.247    0.280    0.210    0.194    0.658
  2   0.209    0.439    0.248    0.280    0.223    0.200    0.659
  3   0.216    0.439    0.248    0.280    0.238    0.206    0.660
  4   0.222    0.439    0.248    0.280    0.255    0.211    0.660
  5   0.229    0.439    0.248    0.280    0.274    0.217    0.660
  6   0.236    0.439    0.248    0.280    0.293    0.225    0.660
  7   0.257    0.440    0.248    0.281    0.326    0.241    0.661
  8   0.267    0.439    0.248    0.281    0.343    0.250    0.661
 ---------------------------------------------------------------------------
PT.     P8       P9
  1   0.494    0.201
  2   0.495    0.202
  3   0.495    0.203
  4   0.495    0.203
  5   0.494    0.203
  6   0.493    0.204
  7   0.494    0.209
  8   0.493    0.211
```

## TABLE XXIX
## RUN 12 REDUCED DATA

### VELOCITY TRIANGLE

| PT. | V1 | V2 | VA1 | VA2 | VU1 | VU2 |
|---|---|---|---|---|---|---|
| 1 | 1436.1 | 369.5 | 363.2 | 241.5 | 1389.4 | -279.7 |
| 2 | 1400.0 | 308.6 | 349.1 | 238.7 | 1355.8 | -195.7 |
| 3 | 1339.4 | 260.7 | 320.7 | 239.1 | 1300.5 | -103.9 |
| 4 | 1303.0 | 245.6 | 300.1 | 240.8 | 1268.0 | -48.6 |
| 5 | 1283.8 | 242.9 | 305.6 | 242.8 | 1246.9 | 9.6 |
| 6 | 1263.5 | 239.0 | 290.0 | 238.9 | 1229.7 | 5.8 |

| | MACH NUMBERS | | | | ANGLES | | | |
|---|---|---|---|---|---|---|---|---|
| PT. | M1 | MA1 | M2 | MA2 | A1 | A2 | B1 | B2 |
| 1 | 1.460 | 0.369 | 0.318 | 0.208 | 75.4 | -49.2 | 68.9 | -71.8 |
| 2 | 1.411 | 0.352 | 0.265 | 0.205 | 75.6 | -39.3 | 67.7 | -71.4 |
| 3 | 1.329 | 0.318 | 0.223 | 0.205 | 76.1 | -23.5 | 65.9 | -71.1 |
| 4 | 1.281 | 0.295 | 0.211 | 0.206 | 76.7 | -11.4 | 65.2 | -70.4 |
| 5 | 1.257 | 0.299 | 0.208 | 0.208 | 76.2 | 2.3 | 63.0 | -69.5 |
| 6 | 1.231 | 0.283 | 0.205 | 0.205 | 76.7 | 1.4 | 61.5 | -71.2 |

### LOSSES

| PT. | ZS | ZSTH | ZR | ZRTH | ZR* | ZI | Y |
|---|---|---|---|---|---|---|---|
| 1 | 0.0715 | 0.0973 | 0.3357 | 0.3122 | 0.3327 | 1.5E-02 | -0.025 |
| 2 | 0.0828 | 0.0972 | 0.3014 | 0.3076 | 0.2991 | 9.9E-03 | -0.009 |
| 3 | 0.0907 | 0.0970 | 0.2807 | 0.2983 | 0.2605 | 4.6E-03 | -0.009 |
| 4 | 0.0829 | 0.0971 | 0.3375 | 0.2985 | 0.3008 | 3.1E-03 | -0.049 |
| 5 | 0.1156 | 0.0965 | 0.3300 | 0.2926 | 0.2884 | 2.8E-04 | 0.039 |
| 6 | 0.0995 | 0.0970 | 0.2511 | 0.2720 | 0.1771 | 7.2E-05 | -0.014 |

## RUN 12 REDUCED DATA

| PT. | P.R. | STPR | H.P. | RTM | STM | AXF | CLF |
|---|---|---|---|---|---|---|---|
| 1 | 3.52 | 3.88 | 81.85 | 422.33 | 350.63 | -73.19 | 8.77 |
| 2 | 3.50 | 3.66 | 85.83 | 391.52 | 341.46 | -46.88 | 11.87 |
| 3 | 3.51 | 3.26 | 90.24 | 355.41 | 328.73 | 6.87 | 15.45 |
| 4 | 3.52 | 2.99 | 89.68 | 333.20 | 320.71 | 27.69 | 18.08 |
| 5 | 3.52 | 3.02 | 88.08 | 312.68 | 315.13 | 46.68 | 20.26 |
| 6 | 3.51 | 2.84 | 93.34 | 308.88 | 310.36 | 72.73 | 22.55 |

```
PT.   MW-DOT     PTO      TTO      PHD     P-TIP    P1      P-HUB
  1  1.93601   59.889   574.1   17.014   19.087   15.444   13.506
  2  1.93250   59.688   572.5   17.033   20.298   16.313   14.437
  3  1.93971   59.875   571.9   17.036   22.230   18.393   16.191
  4  1.93832   59.891   571.5   17.012   23.022   20.027   16.622
  5  1.93916   59.834   571.3   17.018   23.573   19.827   17.555
  6  1.93629   59.730   570.9   17.025   24.296   21.057   18.356
   -------------------------------------------------------------
PT.  PTIP/PTO  P1/PTO   PHUB/PTO    KIS   TURB RE  DEL T    ETA
  1   0.319    0.258     0.226    10.200   2657970   97.80 0.713
  2   0.340    0.273     0.242     7.933   2688230  101.53 0.753
  3   0.371    0.307     0.270     5.954   2693510  103.20 0.783
  4   0.384    0.334     0.278     5.308   2642670  104.14 0.777
  5   0.394    0.331     0.293     4.853   2755010  106.19 0.762
  6   0.407    0.353     0.307     4.224   2675940  107.72 0.808
   -------------------------------------------------------------
PT.   DELTA   THETA   RHP     RMW-DOT    RRTM      RSTM       RN
  1   2.002   1.107  38.866   1.02000   210.994   175.170   11610
  2   1.995   1.104  40.954   1.02000   196.257   171.164   13152
  3   2.001   1.103  42.946   1.02000   177.601   164.269   15240
  4   2.002   1.102  42.683   1.02000   166.459   160.220   16161
  5   2.000   1.101  41.970   1.02000   156.354   157.581   16918
  6   1.996   1.101  44.568   1.02000   154.726   155.467   18154
   --------------------------------------------------------------
PT.   RTH     REFF      RAF        RPM
  1  -0.06  -0.73    137.06     12214
  2  -0.03  -0.53    142.65     13817
  3   0.06  -0.15    156.52     16003
  4   0.12  -0.01    167.47     16964
  5   0.11   0.03    166.30     17755
  6   0.16   0.30    174.50     19046
-----------------------------------------------------------------

                         NOZZLE PRESSURE RATIOS
PT.     P1       P2       P3       P4       P5       P6       P7
  1   0.226    0.440    0.262    0.308    0.254    0.216    0.664
  2   0.243    0.441    0.262    0.307    0.279    0.231    0.664
  3   0.269    0.441    0.262    0.308    0.335    0.255    0.664
  4   0.280    0.441    0.262    0.310    0.349    0.262    0.664
  5   0.296    0.442    0.261    0.309    0.374    0.275    0.665
  6   0.306    0.441    0.261    0.310    0.397    0.284    0.665
   --------------------------------------------------------------
PT.     P8       P9
  1   0.495    0.233
  2   0.494    0.233
  3   0.494    0.235
  4   0.285    0.236
  5   0.284    0.237
  6   0.285    0.238
```

## TABLE XXX
## RUN 13 REDUCED DATA

### VELOCITY TRIANGLE

| PT. | V1 | V2 | VA1 | VA2 | VU1 | VU2 |
|---|---|---|---|---|---|---|
| 1 | 1426.0 | 357.6 | 376.2 | 241.3 | 1375.5 | -264.0 |
| 2 | 1409.1 | 335.4 | 356.1 | 239.3 | 1363.3 | -235.0 |
| 3 | 1393.7 | 304.0 | 345.5 | 239.2 | 1350.2 | -187.5 |
| 4 | 1374.7 | 276.5 | 338.6 | 237.2 | 1332.3 | -142.0 |
| 5 | 1329.2 | 259.3 | 320.0 | 237.4 | 1290.1 | -104.3 |
| 6 | 1311.2 | 246.9 | 317.5 | 238.9 | 1272.2 | -62.5 |
| 7 | 1253.7 | 241.7 | 305.6 | 241.6 | 1215.9 | -3.9 |
| 8 | 1232.4 | 248.0 | 297.3 | 242.8 | 1196.0 | 50.8 |

| | MACH NUMBERS | | | | ANGLES | | | |
|---|---|---|---|---|---|---|---|---|
| PT. | M1 | MA1 | M2 | MA2 | A1 | A2 | B1 | B2 |
| 1 | 1.445 | 0.381 | 0.307 | 0.207 | 74.7 | -47.6 | 68.1 | -71.3 |
| 2 | 1.424 | 0.360 | 0.288 | 0.206 | 75.4 | -44.5 | 68.1 | -71.6 |
| 3 | 1.402 | 0.347 | 0.261 | 0.205 | 75.6 | -38.1 | 67.6 | -71.4 |
| 4 | 1.375 | 0.339 | 0.237 | 0.203 | 75.7 | -30.9 | 66.7 | -71.2 |
| 5 | 1.313 | 0.316 | 0.222 | 0.203 | 76.1 | -23.7 | 65.6 | -71.3 |
| 6 | 1.289 | 0.312 | 0.211 | 0.204 | 76.0 | -14.7 | 64.0 | -71.0 |
| 7 | 1.215 | 0.296 | 0.207 | 0.207 | 75.9 | -0.9 | 59.7 | -71.1 |
| 8 | 1.188 | 0.287 | 0.212 | 0.208 | 76.0 | 11.8 | 57.4 | -70.6 |

### LOSSES

| PT. | ZS | ZSTH | ZR | ZRTH | ZR* | ZI | Y |
|---|---|---|---|---|---|---|---|
| 1 | 0.1005 | 0.0955 | 0.3192 | 0.3123 | 0.3223 | 1.1E-02 | 0.031 |
| 2 | 0.0856 | 0.0974 | 0.3028 | 0.3083 | 0.3014 | 1.1E-02 | -0.001 |
| 3 | 0.0831 | 0.0973 | 0.2982 | 0.3064 | 0.2942 | 9.4E-03 | -0.013 |
| 4 | 0.0899 | 0.0973 | 0.2731 | 0.3021 | 0.2675 | 6.6E-03 | -0.001 |
| 5 | 0.1004 | 0.0956 | 0.2610 | 0.2961 | 0.2403 | 3.9E-03 | -0.004 |
| 6 | 0.1137 | 0.0959 | 0.2353 | 0.2884 | 0.2053 | 1.2E-03 | 0.036 |
| 7 | 0.1485 | 0.0958 | 0.1763 | 0.2648 | 0.1034 | 1.5E-03 | 0.121 |
| 8 | 0.1524 | 0.0943 | 0.2068 | 0.2546 | 0.1089 | 6.3E-03 | 0.115 |

## RUN 13 REDUCED DATA

| PT. | P.R. | STPR | H.P. | RTM | STM | AXF | CLF |
|---|---|---|---|---|---|---|---|
| 1 | 3.55 | 3.99 | 79.95 | 416.97 | 348.95 | -69.55 | 10.30 |
| 2 | 3.51 | 3.75 | 84.17 | 405.51 | 345.09 | -60.62 | 10.13 |
| 3 | 3.53 | 3.61 | 87.13 | 390.31 | 342.06 | -40.45 | 12.26 |
| 4 | 3.52 | 3.50 | 88.76 | 373.07 | 336.63 | -23.08 | 14.09 |
| 5 | 3.52 | 3.22 | 89.69 | 352.33 | 325.59 | 7.73 | 15.91 |
| 6 | 3.53 | 3.17 | 91.25 | 337.65 | 321.60 | 30.28 | 18.52 |
| 7 | 3.54 | 2.96 | 92.76 | 308.45 | 307.44 | 64.01 | 22.53 |
| 8 | 3.54 | 2.85 | 91.87 | 289.39 | 302.45 | 86.35 | 24.10 |

```
PT.    MW-DOT       PTO       TTO      PHD     P-TIP     P1      P-HUB
  1  1.94983     60.216     574.3   16.950   19.185   15.087   13.625
  2  1.94901     60.001     572.8   17.118   19.841   15.998   14.014
  3  1.95315     60.059     572.9   17.006   20.479   16.655   14.572
  4  1.95062     59.909     573.1   17.013   21.251   17.138   15.196
  5  1.94853     59.851     573.3   17.006   22.275   18.567   16.102
  6  1.95096     59.952     573.4   16.967   22.987   18.920   16.967
  7  1.95055     60.010     574.2   16.949   24.114   20.261   18.082
  8  1.94933     60.034     574.5   16.959   24.792   21.046   18.827
   -----------------------------------------------------------------
PT.  PTIP/PTO   P1/PTO   PHUB/PTO    KIS     TURB RE   DEL T    ETA
  1   0.319     0.251     0.226    10.351   2808940   90.46 0.698
  2   0.331     0.267     0.234     8.846   2720590   99.88 0.735
  3   0.341     0.277     0.243     7.676   2699390   96.57 0.757
  4   0.355     0.286     0.254     6.738   2708710   96.23 0.776
  5   0.372     0.310     0.269     5.896   2716240   97.27 0.783
  6   0.383     0.316     0.283     5.266   2761740   96.72 0.790
  7   0.402     0.338     0.301     4.301   2849530   96.27 0.794
  8   0.413     0.351     0.314     3.865   2841450   98.72 0.785
   ----------------------------------------------------------------
PT.    DELTA   THETA    RHP     RMW-DOT    RRTM      RSTM       RN
  1    2.013   1.107  37.755   1.02000   207.184   173.383   11485
  2    2.005   1.104  39.941   1.02000   202.212   172.080   12449
  3    2.007   1.104  41.305   1.02000   194.445   170.405   13388
  4    2.002   1.105  42.172   1.02000   186.319   168.118   14265
  5    2.000   1.105  42.649   1.02000   176.129   162.765   15261
  6    2.004   1.105  43.312   1.02000   168.507   160.497   16200
  7    2.006   1.107  43.955   1.02000   153.787   153.283   18014
  8    2.006   1.107  43.509   1.02000   144.228   150.736   19013
   -----------------------------------------------------------------
PT.    RTH     REFF       RAF         RPM
  1  -0.09   -0.80     135.30       12085
  2  -0.04   -0.59     140.83       13081
  3  -0.01   -0.48     145.11       14070
  4   0.00   -0.36     148.23       14995
  5   0.06   -0.12     157.74       16044
  6   0.08    0.01     160.25       17032
  7   0.13    0.31     169.54       18953
  8   0.16    0.40     174.90       20009
-----------------------------------------------------------------


                        NOZZLE PRESSURE RATIOS
PT.      P1        P2        P3        P4        P5        P6        P7
  1    0.227     0.440     0.261     0.313     0.262     0.217     0.664
  2    0.234     0.441     0.258     0.305     0.269     0.224     0.666
  3    0.243     0.441     0.259     0.306     0.290     0.231     0.666
  4    0.254     0.441     0.259     0.306     0.316     0.240     0.667
  5    0.269     0.441     0.262     0.316     0.337     0.254     0.667
  6    0.283     0.442     0.261     0.312     0.356     0.264     0.667
  7    0.301     0.441     0.259     0.309     0.389     0.278     0.667
  8    0.312     0.440     0.261     0.319     0.427     0.290     0.665
   -----------------------------------------------------------------
PT.      P8        P9
  1    0.282     0.232
  2    0.286     0.230
  3    0.284     0.231
  4    0.284     0.232
  5    0.284     0.236
  6    0.283     0.237
  7    0.282     0.237
  8    0.282     0.243
```

## TABLE XXXI

### PARAMETER CONVERGENCE INVESTIGATION

| SCANS | AX FORCE | CL FORCE | DYNA Q | STATOR Q | RPM |
|---|---|---|---|---|---|
| 10 | -124.39 | 9.125 | 397.28 | 347.45 | 11418 |
| 20 | -123.67 | 9.218 | 393.22 | 347.17 | 11508 |
| 30 | -124.18 | 9.172 | 392.82 | 347.18 | 11471 |
| 40 | -124.55 | 9.165 | 393.19 | 347.24 | 11465 |
| 50 | -124.74 | 9.157 | 392.77 | 347.29 | 11453 |
| 60 | -124.60 | 9.167 | 392.06 | 347.26 | 11461 |
| 70 | -124.50 | 9.172 | 391.66 | 347.21 | 11465 |
| 80 | -124.29 | 9.186 | 391.31 | 347.14 | 11487 |
| 90 | -124.07 | 9.186 | 391.17 | 347.10 | 11500 |
| 100 | -124.30 | 9.172 | 391.45 | 347.14 | 11487 |

# TABLE XXXII

## RUN 10 UNCERTAINTY DATA

| PT. | RAF | +/- | % ERROR | P1/PTO | +/- | % ERROR |
|---|---|---|---|---|---|---|
| 1 | 130.79 | 1.997 | 1.527 | 0.2427 | 0.0173 | 1.100 |
| 2 | 132.31 | 1.997 | 1.509 | 0.2449 | 0.0185 | 1.082 |
| 3 | 136.78 | 1.997 | 1.460 | 0.2586 | 0.0194 | 1.015 |
| 4 | 138.09 | 1.997 | 1.446 | 0.2602 | 0.0213 | 1.003 |
| 5 | 141.09 | 1.997 | 1.415 | 0.2682 | 0.0229 | 0.966 |
| 6 | 145.51 | 1.997 | 1.372 | 0.2794 | 0.0242 | 0.919 |
| 7 | 149.26 | 1.997 | 1.338 | 0.2889 | 0.0254 | 0.883 |
| 8 | 168.25 | 1.997 | 1.187 | 0.3374 | 0.0221 | 0.734 |
| 9 | 147.43 | 1.997 | 1.354 | 0.2768 | 0.0312 | 0.920 |

| PT. | Z1 | +/- | % ERROR | Z3 | +/- | % ERROR |
|---|---|---|---|---|---|---|
| 1 | 0.0522 | 0.0310 | 59.33 | 0.4167 | 0.0415 | 9.96 |
| 2 | 0.0643 | 0.0309 | 48.03 | 0.3751 | 0.0473 | 12.60 |
| 3 | 0.0565 | 0.0303 | 53.66 | 0.3464 | 0.0492 | 14.19 |
| 4 | 0.0785 | 0.0304 | 38.74 | 0.3211 | 0.0557 | 17.33 |
| 5 | 0.0832 | 0.0302 | 36.28 | 0.2972 | 0.0599 | 20.15 |
| 6 | 0.0898 | 0.0299 | 33.29 | 0.2622 | 0.0638 | 24.35 |
| 7 | 0.0966 | 0.0298 | 30.79 | 0.2253 | 0.0682 | 30.28 |
| 8 | 0.0462 | 0.0284 | 61.45 | 0.3379 | 0.0434 | 12.85 |
| 9 | 0.1633 | 0.0306 | 18.72 | 0.0479 | 0.1073 | 223.91 |

# TABLE XXXIII

## RUN 11 UNCERTAINTY DATA

| PT. | RAF | +/- | % ERROR | P1/PTO | +/- | % ERROR |
|---|---|---|---|---|---|---|
| 1 | 163.11 | 1.997 | 1.224 | 0.2413 | 0.0139 | 0.886 |
| 2 | 162.61 | 1.997 | 1.228 | 0.2383 | 0.0157 | 0.898 |
| 3 | 169.62 | 1.997 | 1.177 | 0.2570 | 0.0165 | 0.823 |
| 4 | 172.91 | 1.997 | 1.155 | 0.2619 | 0.0173 | 0.799 |
| 5 | 175.21 | 1.997 | 1.140 | 0.2646 | 0.0187 | 0.786 |
| 6 | 180.19 | 1.997 | 1.108 | 0.2765 | 0.0196 | 0.747 |
| 7 | 183.74 | 1.997 | 1.087 | 0.2832 | 0.0212 | 0.726 |
| 8 | 195.93 | 1.997 | 1.019 | 0.3080 | 0.0205 | 0.655 |

| PT. | Z1 | +/- | % ERROR | Z3 | +/- | % ERROR |
|---|---|---|---|---|---|---|
| 1 | 0.0583 | 0.0249 | 42.71 | 0.4112 | 0.0340 | 8.28 |
| 2 | 0.0824 | 0.0252 | 30.64 | 0.3498 | 0.0427 | 12.22 |
| 3 | 0.0746 | 0.0246 | 33.00 | 0.3313 | 0.0429 | 12.95 |
| 4 | 0.0815 | 0.0244 | 29.97 | 0.3057 | 0.0458 | 15.00 |
| 5 | 0.0983 | 0.0244 | 24.84 | 0.2762 | 0.0511 | 18.49 |
| 6 | 0.0987 | 0.0242 | 24.49 | 0.2408 | 0.0539 | 22.39 |
| 7 | 0.1159 | 0.0242 | 20.86 | 0.2063 | 0.0596 | 28.88 |
| 8 | 0.0994 | 0.0235 | 23.66 | 0.2480 | 0.0500 | 20.17 |

## TABLE XXXIV

## RUN 12 UNCERTAINTY DATA

| PT. | RAF | +/- | % ERROR | P1/PTO | +/- | % ERROR |
|---|---|---|---|---|---|---|
| 1 | 137.06 | 1.997 | 1.457 | 0.2583 | 0.0192 | 1.009 |
| 2 | 142.65 | 1.997 | 1.400 | 0.2736 | 0.0217 | 0.942 |
| 3 | 156.52 | 1.997 | 1.276 | 0.3075 | 0.0232 | 0.816 |
| 4 | 167.47 | 1.997 | 1.192 | 0.3348 | 0.0226 | 0.738 |
| 5 | 166.30 | 1.997 | 1.201 | 0.3316 | 0.0250 | 0.748 |
| 6 | 174.50 | 1.997 | 1.144 | 0.3528 | 0.0245 | 0.698 |

| PT. | Z1 | +/- | % ERROR | Z3 | +/- | % ERROR |
|---|---|---|---|---|---|---|
| 1 | 0.0672 | 0.0303 | 45.02 | 0.3403 | 0.0490 | 14.41 |
| 2 | 0.0787 | 0.0299 | 38.03 | 0.3061 | 0.0551 | 18.01 |
| 3 | 0.0869 | 0.0291 | 33.53 | 0.2847 | 0.0540 | 18.98 |
| 4 | 0.0766 | 0.0287 | 37.42 | 0.3427 | 0.0443 | 12.92 |
| 5 | 0.1116 | 0.0291 | 26.07 | 0.3338 | 0.0501 | 15.02 |
| 6 | 0.0953 | 0.0288 | 30.25 | 0.2546 | 0.0518 | 20.35 |

## TABLE XXXV

## RUN 13 UNCERTAINTY DATA

| PT. | RAF | +/- | % ERROR | P1/PTO | +/- | % ERROR |
|---|---|---|---|---|---|---|
| 1 | 135.30 | 1.997 | 1.476 | 0.2506 | 0.0211 | 1.046 |
| 2 | 140.83 | 1.997 | 1.418 | 0.2664 | 0.0213 | 0.971 |
| 3 | 145.11 | 1.997 | 1.376 | 0.2769 | 0.0221 | 0.924 |
| 4 | 148.23 | 1.997 | 1.347 | 0.2855 | 0.0239 | 0.893 |
| 5 | 157.74 | 1.997 | 1.266 | 0.3097 | 0.0245 | 0.811 |
| 6 | 160.25 | 1.997 | 1.246 | 0.3151 | 0.0257 | 0.794 |
| 7 | 169.54 | 1.997 | 1.178 | 0.3372 | 0.0272 | 0.733 |
| 8 | 174.90 | 1.997 | 1.142 | 0.3503 | 0.0273 | 0.702 |

| PT. | Z1 | +/- | % ERROR | Z3 | +/- | % ERROR |
|---|---|---|---|---|---|---|
| 1 | 0.0995 | 0.0310 | 31.13 | 0.3204 | 0.0572 | 17.85 |
| 2 | 0.0878 | 0.0302 | 34.39 | 0.3001 | 0.0558 | 18.60 |
| 3 | 0.0876 | 0.0298 | 34.04 | 0.2929 | 0.0564 | 19.27 |
| 4 | 0.0969 | 0.0298 | 30.73 | 0.2646 | 0.0616 | 23.28 |
| 5 | 0.1073 | 0.0294 | 27.37 | 0.2533 | 0.0591 | 23.32 |
| 6 | 0.1199 | 0.0294 | 24.50 | 0.2281 | 0.0631 | 27.64 |
| 7 | 0.1536 | 0.0294 | 19.16 | 0.1707 | 0.0670 | 39.23 |
| 8 | 0.1563 | 0.0294 | 18.78 | 0.2030 | 0.0622 | 30.64 |

## TABLE XXXVI

## RUN 14 UNCERTAINTY DATA

| PT. | RAF | +/- | % ERROR | P1/PTO | +/- | % ERROR |
|---|---|---|---|---|---|---|
| 1 | 132.80 | 1.997 | 1.504 | 0.2479 | 0.0209 | 1.074 |
| 2 | 137.14 | 1.997 | 1.456 | 0.2569 | 0.0211 | 1.017 |
| 3 | 145.50 | 1.997 | 1.372 | 0.2794 | 0.0210 | 0.916 |
| 4 | 145.19 | 1.997 | 1.375 | 0.2783 | 0.0235 | 0.922 |
| 5 | 148.96 | 1.997 | 1.340 | 0.2863 | 0.0249 | 0.888 |
| 6 | 153.39 | 1.997 | 1.302 | 0.2995 | 0.0269 | 0.846 |
| 7 | 164.56 | 1.997 | 1.213 | 0.3262 | 0.0271 | 0.763 |
| 8 | 167.50 | 1.997 | 1.192 | 0.3327 | 0.0285 | 0.746 |

| PT. | Z1 | +/- | % ERROR | Z3 | +/- | % ERROR |
|---|---|---|---|---|---|---|
| 1 | 0.0824 | 0.0312 | 37.91 | 0.3624 | 0.0538 | 14.84 |
| 2 | 0.0823 | 0.0305 | 37.09 | 0.3245 | 0.0554 | 7.07 |
| 3 | 0.0637 | 0.0295 | 46.33 | 0.3528 | 0.0486 | 13.76 |
| 4 | 0.0860 | 0.0298 | 34.70 | 0.3121 | 0.0581 | 18.62 |
| 5 | 0.1026 | 0.0297 | 29.00 | 0.2528 | 0.0650 | 25.70 |
| 6 | 0.1140 | 0.0297 | 26.08 | 0.2271 | 0.0695 | 30.60 |
| 7 | 0.1279 | 0.0294 | 22.96 | 0.2509 | 0.0622 | 24.78 |
| 8 | 0.1487 | 0.0295 | 19.83 | 0.1915 | 0.0693 | 36.18 |

## TABLE XXXVII

## RUN 15 UNCERTAINTY DATA

| PT. | RAF | +/- | % ERROR | P1/PTO | +/- | % ERROR |
|---|---|---|---|---|---|---|
| 1 | 127.73 | 1.997 | 1.563 | 0.2308 | 0.0196 | 1.170 |
| 2 | 131.71 | 1.997 | 1.516 | 0.2417 | 0.0207 | 1.102 |
| 3 | 134.85 | 1.997 | 1.481 | 0.2504 | 0.0217 | 1.054 |
| 4 | 134.51 | 1.997 | 1.484 | 0.2489 | 0.0247 | 1.065 |
| 5 | 141.47 | 1.997 | 1.411 | 0.2666 | 0.0239 | 0.970 |
| 6 | 143.23 | 1.997 | 1.394 | 0.2705 | 0.0258 | 0.953 |
| 7 | 153.94 | 1.997 | 1.297 | 0.2990 | 0.0269 | 0.847 |
| 8 | 156.22 | 1.997 | 1.278 | 0.3045 | 0.0286 | 0.830 |

| PT. | Z1 | +/- | % ERROR | Z3 | +/- | % ERROR |
|---|---|---|---|---|---|---|
| 1 | 0.0886 | 0.0321 | 36.23 | 0.3417 | 0.0560 | 16.39 |
| 2 | 0.0917 | 0.0315 | 34.37 | 0.3282 | 0.0574 | 17.49 |
| 3 | 0.0923 | 0.0311 | 33.68 | 0.3017 | 0.0604 | 20.03 |
| 4 | 0.1161 | 0.0316 | 27.21 | 0.2360 | 0.0759 | 32.15 |
| 5 | 0.1001 | 0.0304 | 30.33 | 0.2454 | 0.0675 | 27.52 |
| 6 | 0.1162 | 0.0304 | 26.20 | 0.1890 | 0.0774 | 40.93 |
| 7 | 0.1212 | 0.0298 | 24.56 | 0.1884 | 0.0730 | 38.75 |
| 8 | 0.1414 | 0.0299 | 21.16 | 0.1555 | 0.0793 | 50.99 |

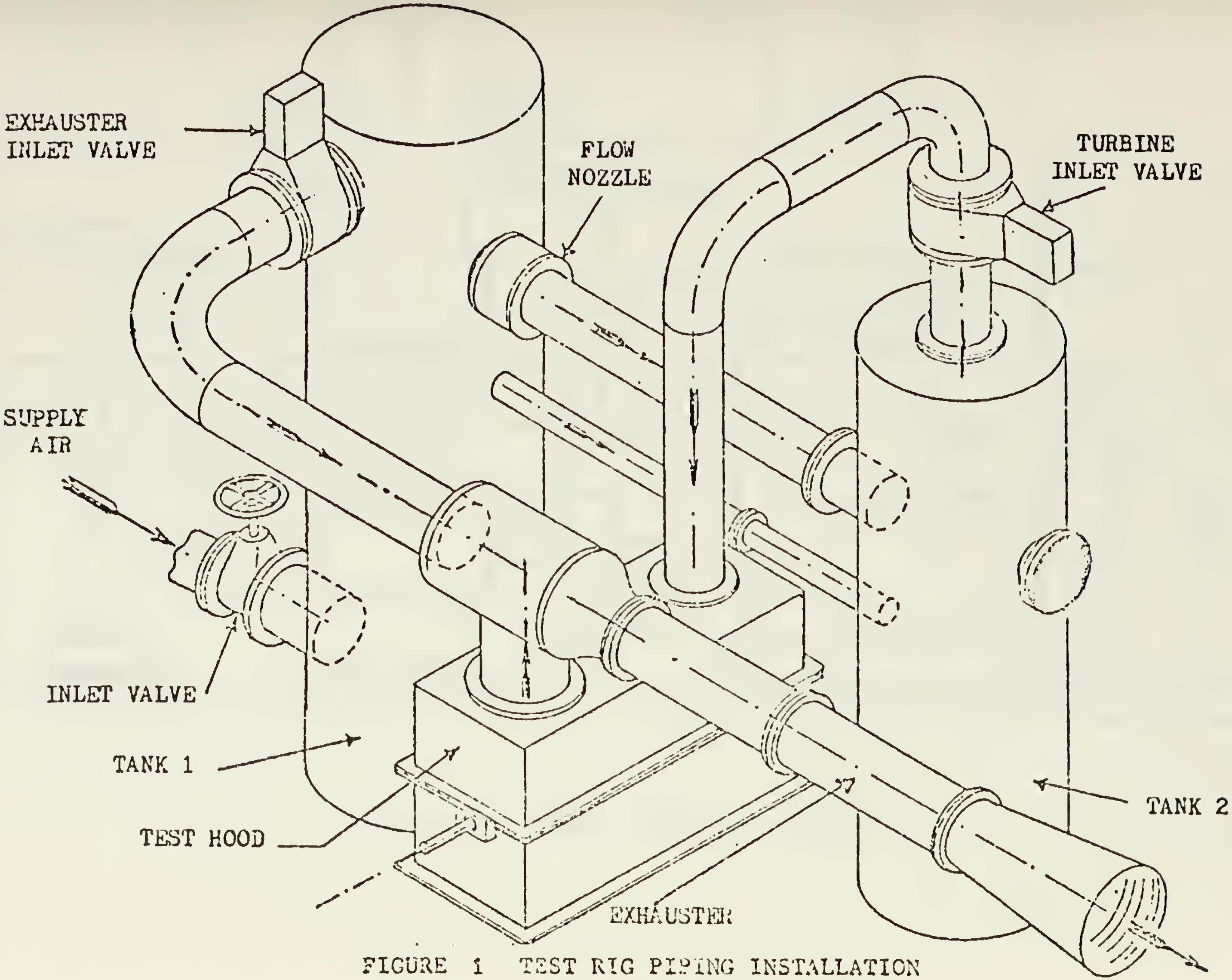


FIGURE 1 TEST RIG PIPING INSTALLATION

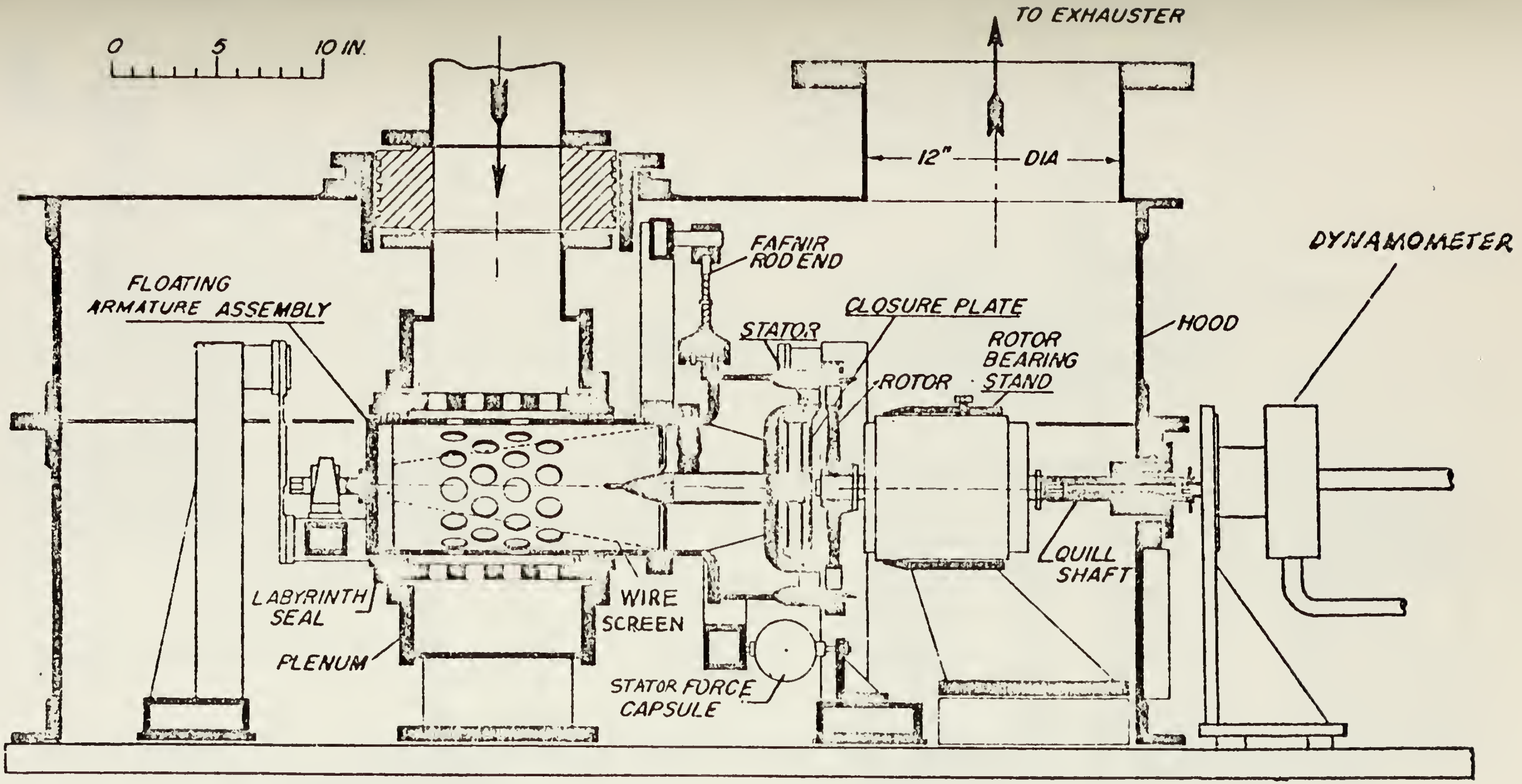


FIGURE 2 THE TURBINE TEST RIG

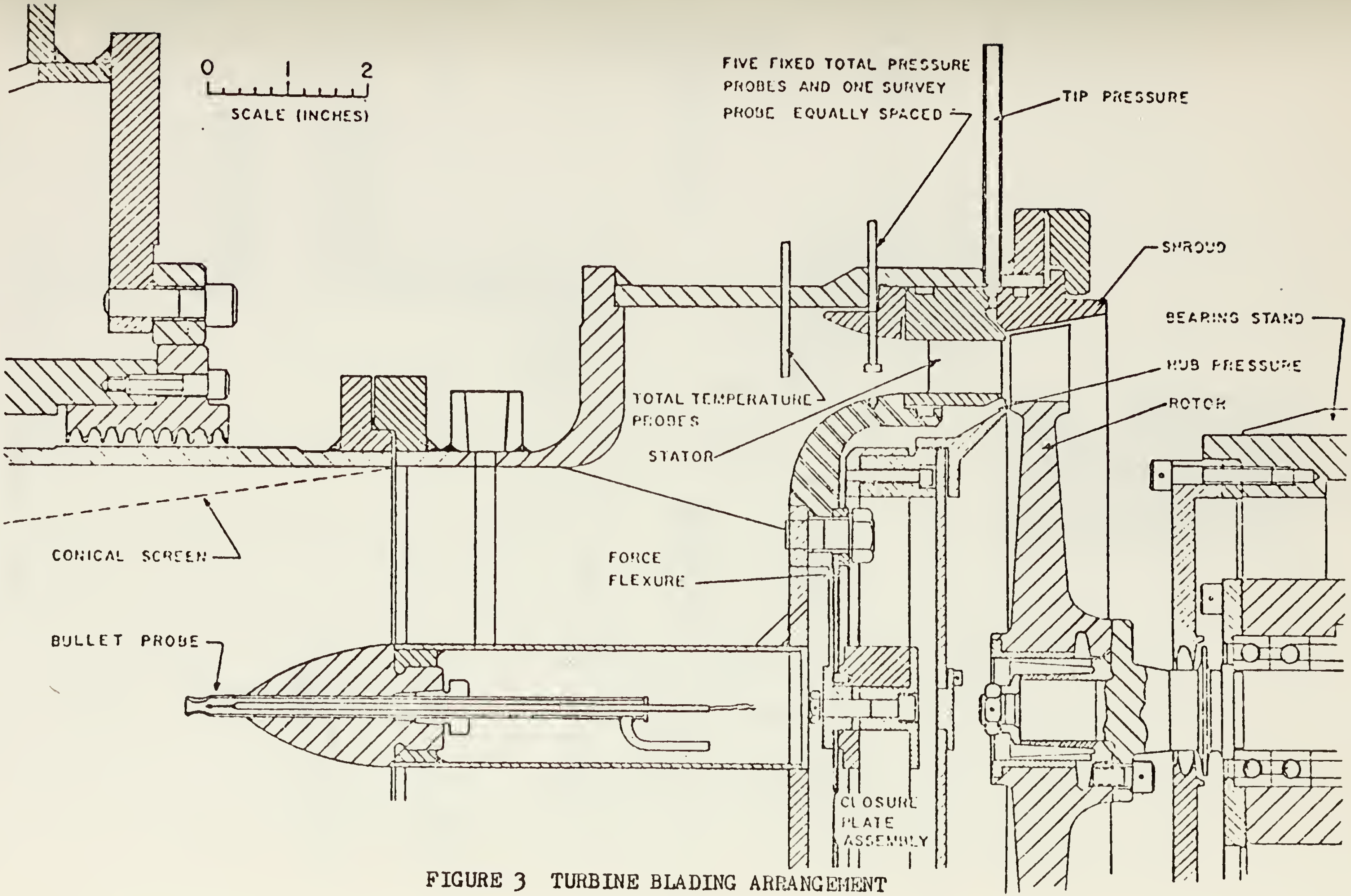


FIGURE 3 TURBINE BLADING ARRANGEMENT

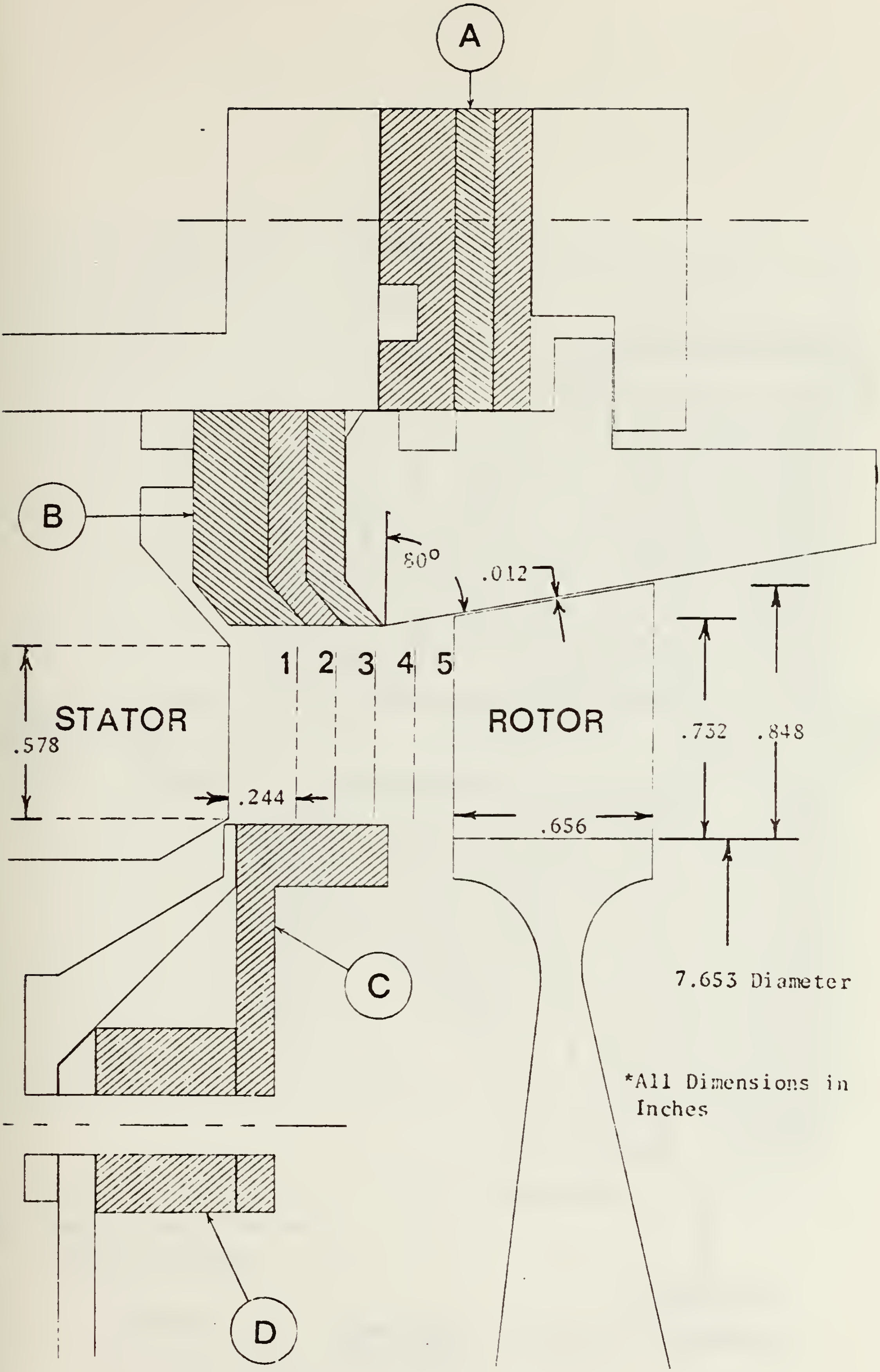
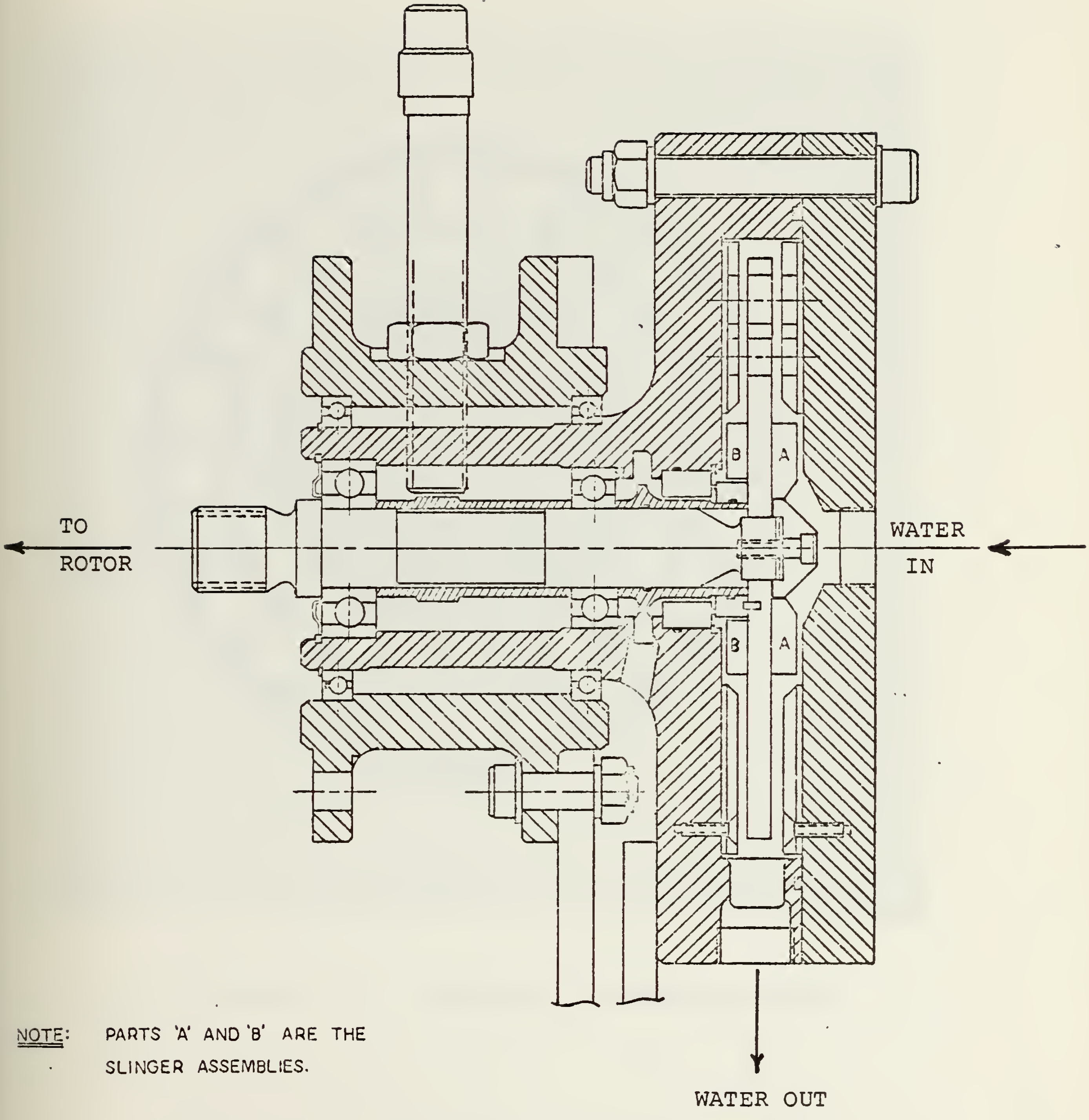


FIGURE 4. INTERBLADE PASSAGE



NOTE: PARTS 'A' AND 'B' ARE THE SLINGER ASSEMBLIES.

FIGURE 5. a) Waterbrake "Slinger" Assemblies - Side View

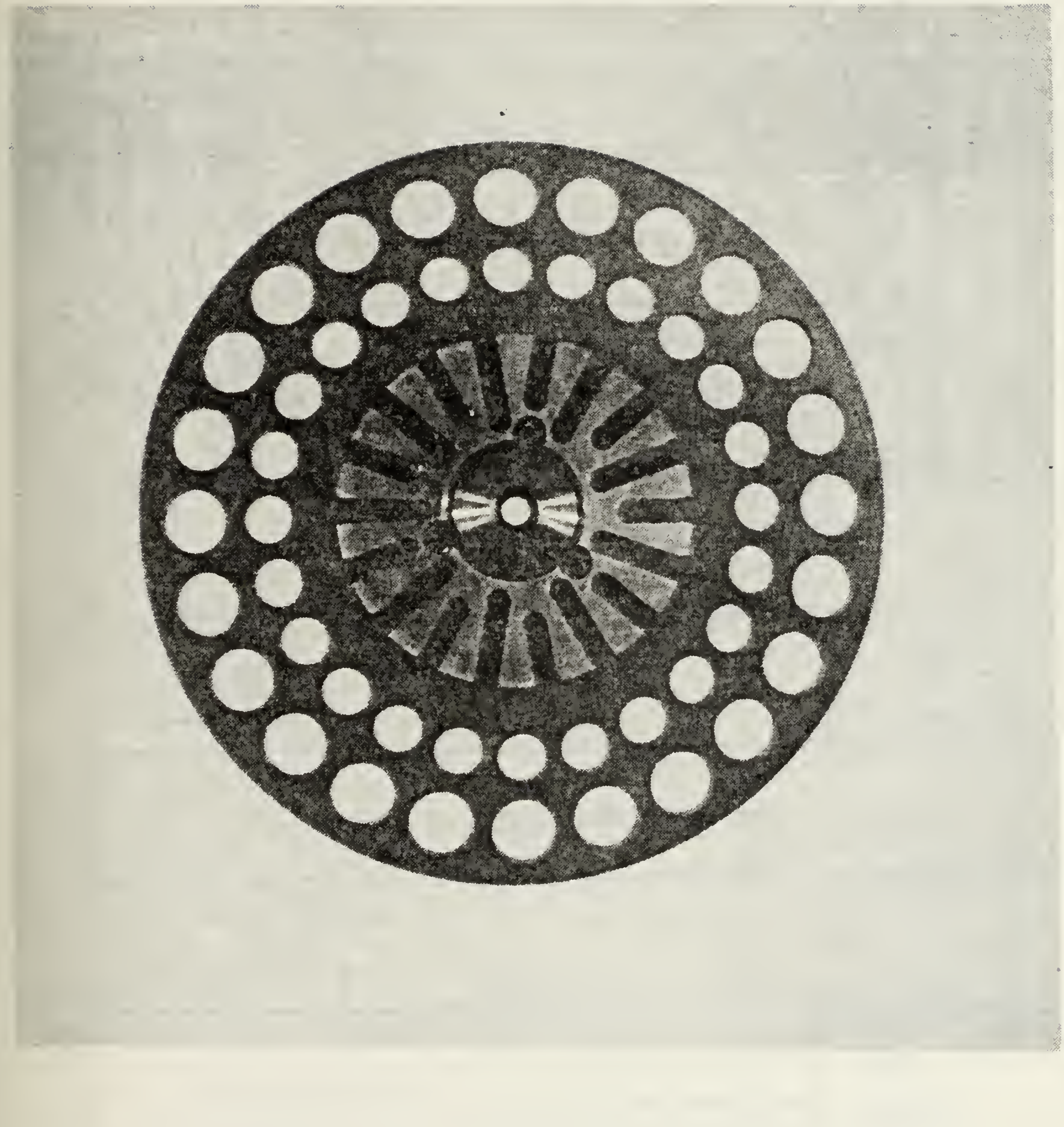


FIGURE 5. b) CLOSE-UP OF SLINGER ASSEMBLY

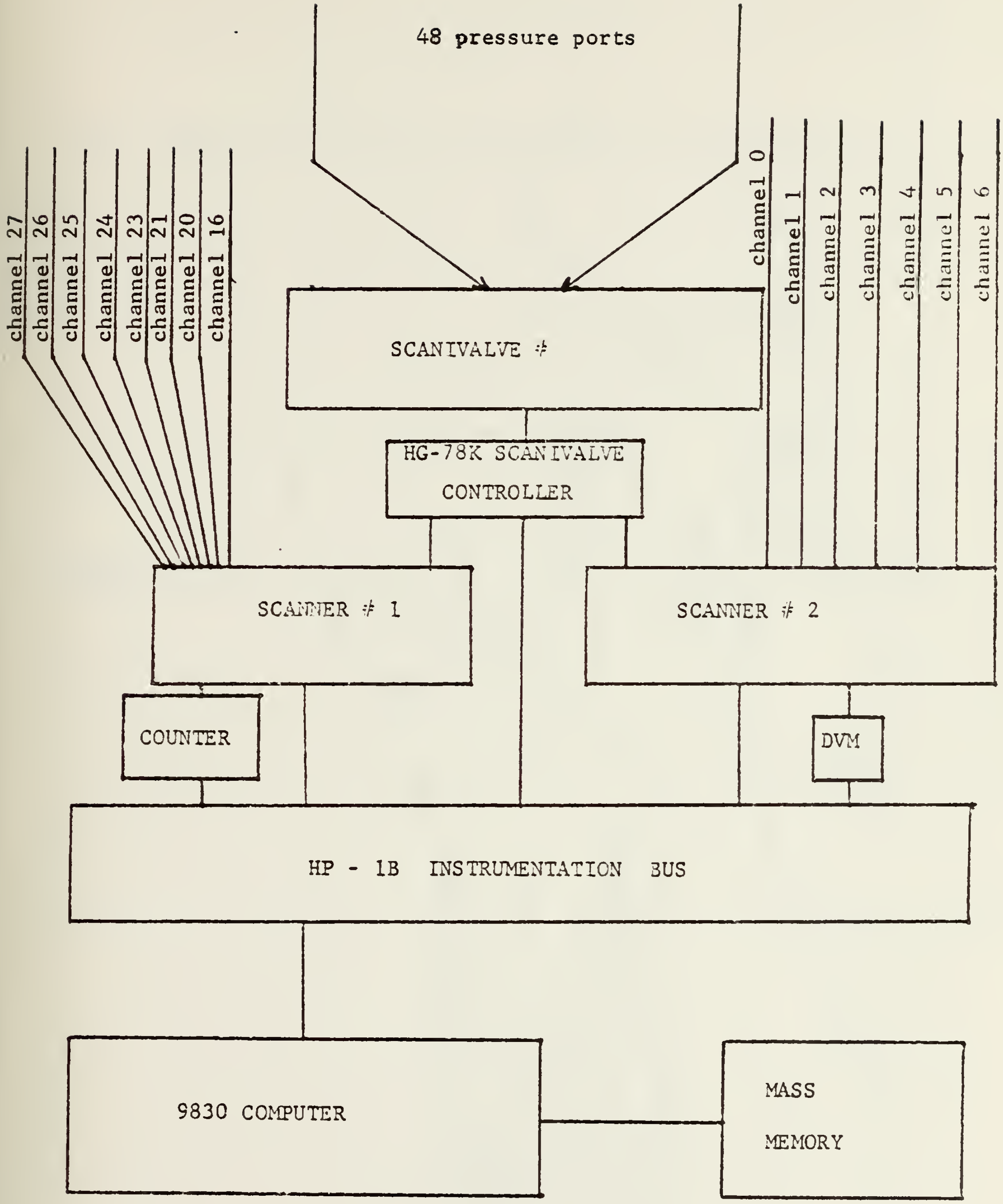
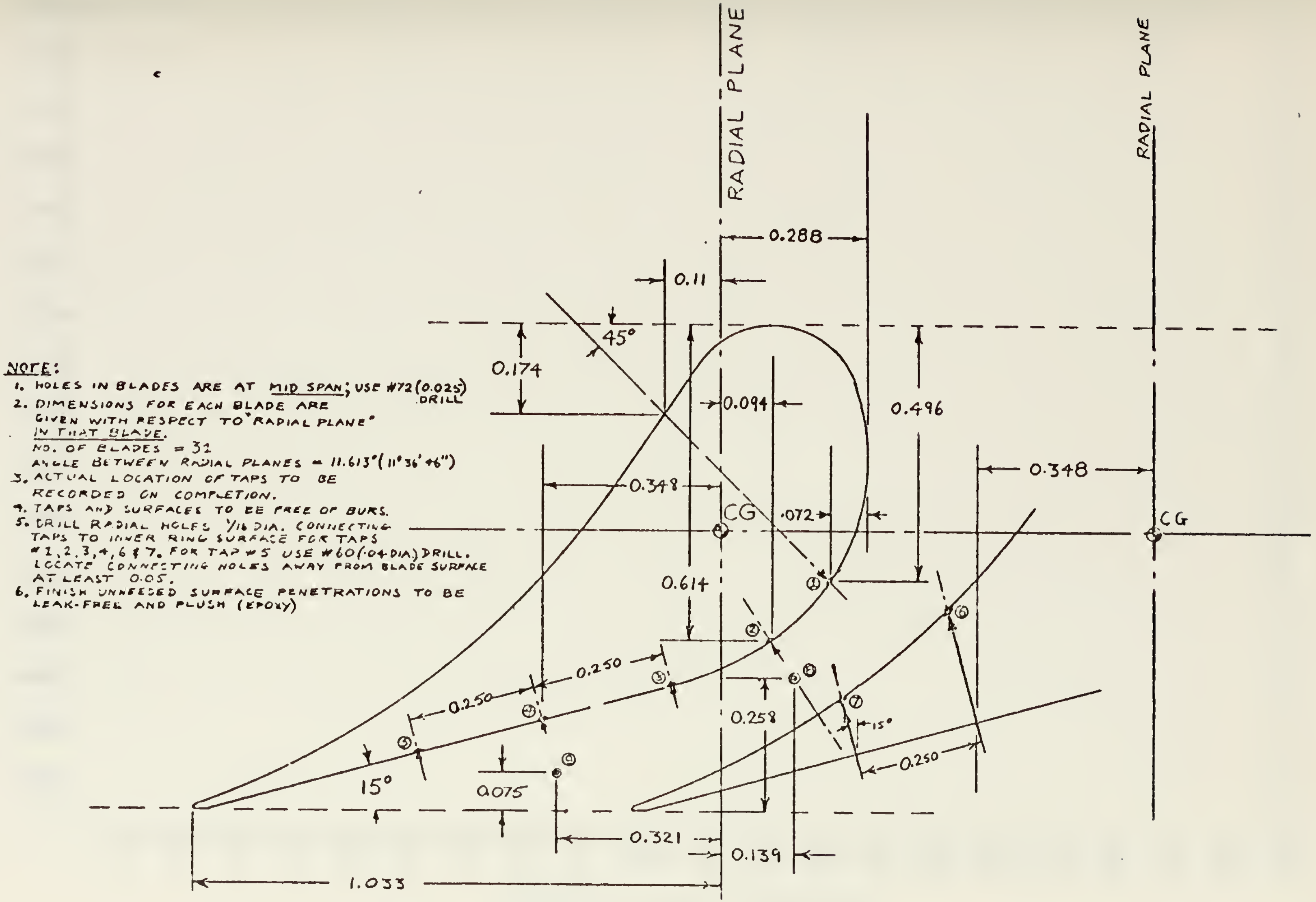


FIGURE 6. Instrumentation System



NOTE:
1. HOLES IN BLADES ARE AT MID SPAN; USE #72 (0.025) DRILL
2. DIMENSIONS FOR EACH BLADE ARE GIVEN WITH RESPECT TO "RADIAL PLANE" IN THAT BLADE.
   NO. OF BLADES = 31
   ANGLE BETWEEN RADIAL PLANES = 11.613° (11°36'46")
3. ACTUAL LOCATION OF TAPS TO BE RECORDED ON COMPLETION.
4. TAPS AND SURFACES TO BE FREE OF BURS.
5. DRILL RADIAL HOLES 1/16 DIA. CONNECTING TAPS TO INNER RING SURFACE FOR TAPS #1, 2, 3, 4, 6 & 7. FOR TAP #5 USE #60 (.04 DIA.) DRILL. LOCATE CONNECTING HOLES AWAY FROM BLADE SURFACE AT LEAST 0.05.
6. FINISH UNNEEDED SURFACE PENETRATIONS TO BE LEAK-FREE AND FLUSH (EPOXY)

FIGURE 7. STATOR PRESSURE TAP LOCATIONS

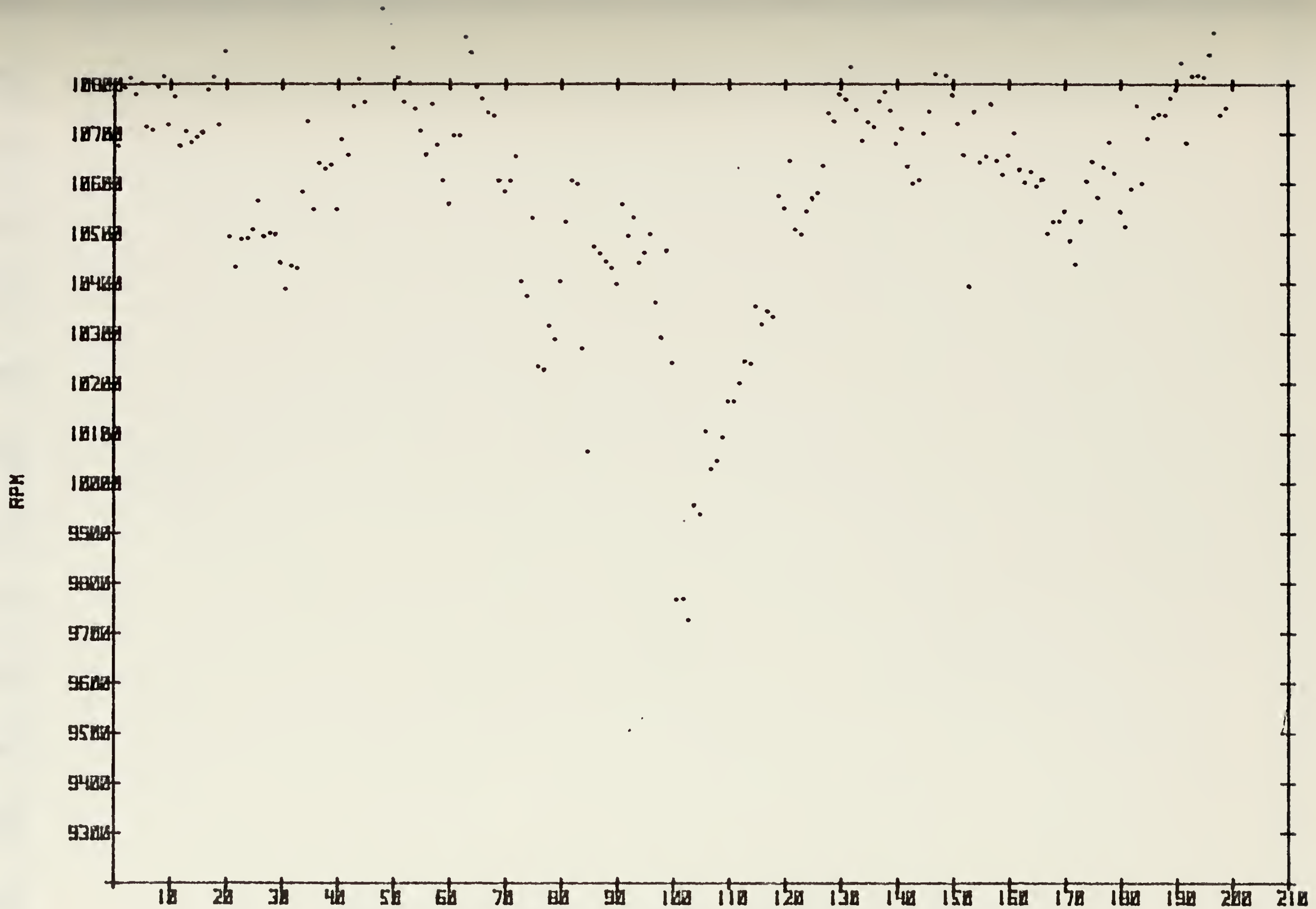


FIGURE 8. RPM SAMPLES (10610 RPM, No slinger)

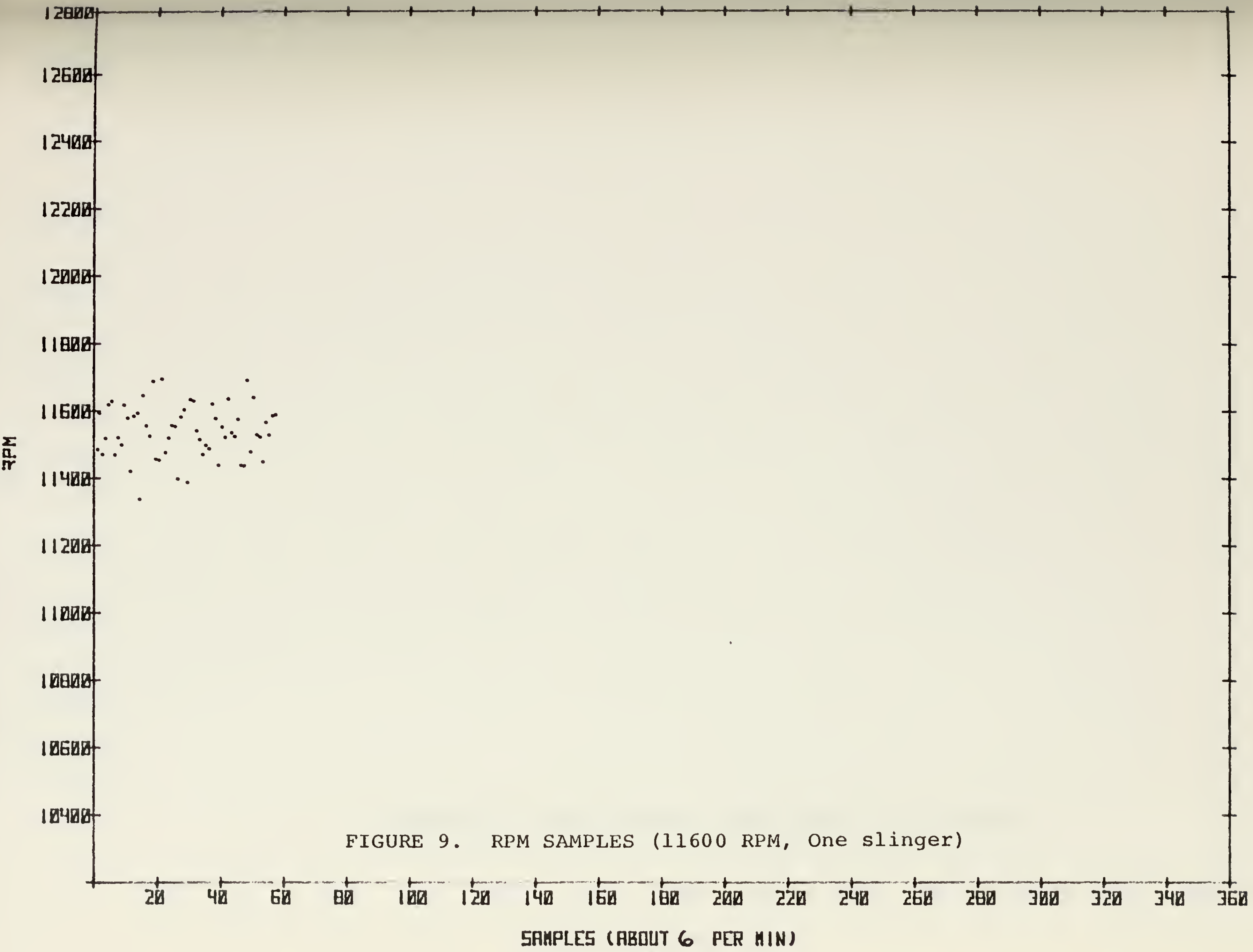


FIGURE 9. RPM SAMPLES (11600 RPM, One slinger)

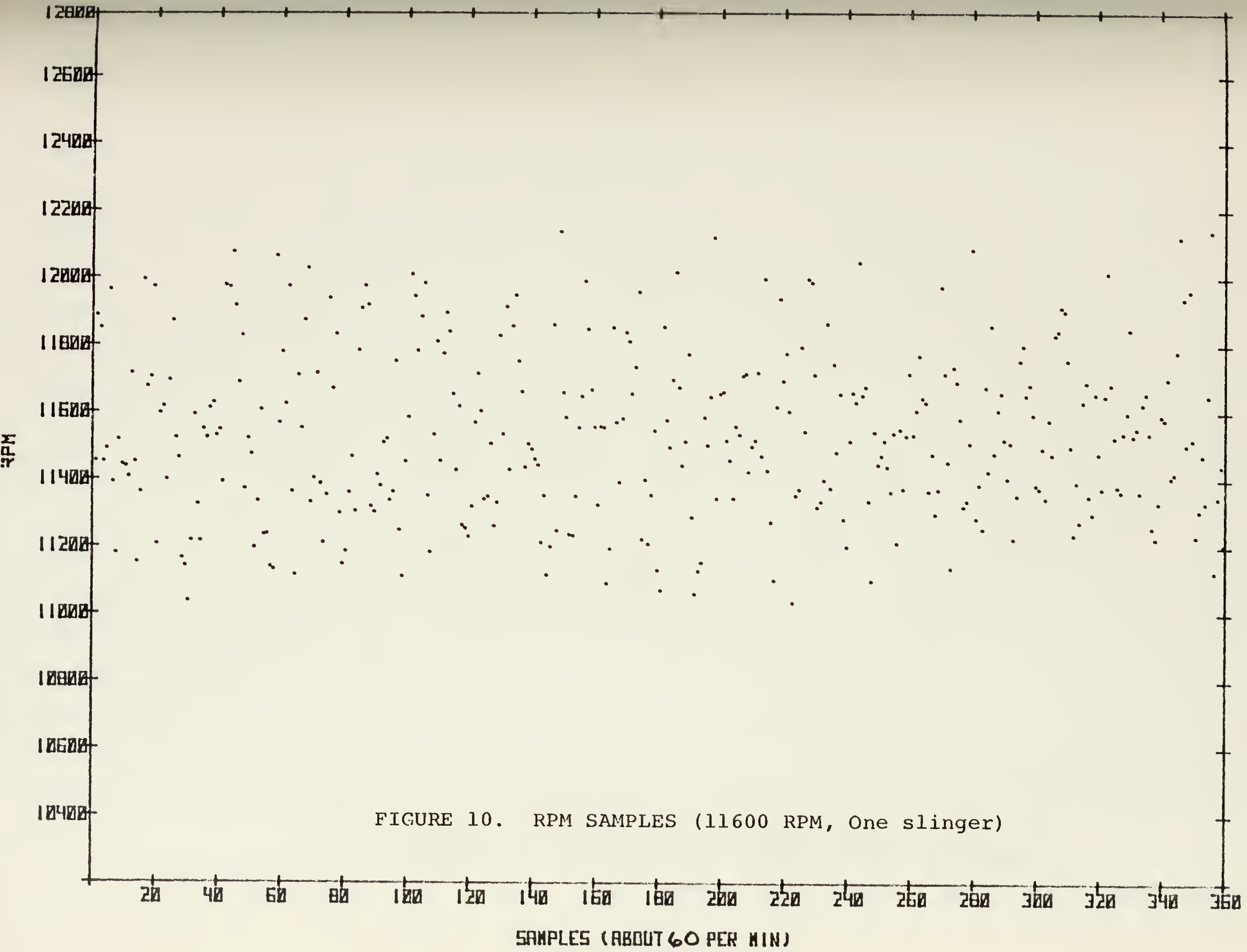


FIGURE 10. RPM SAMPLES (11600 RPM, One slinger)

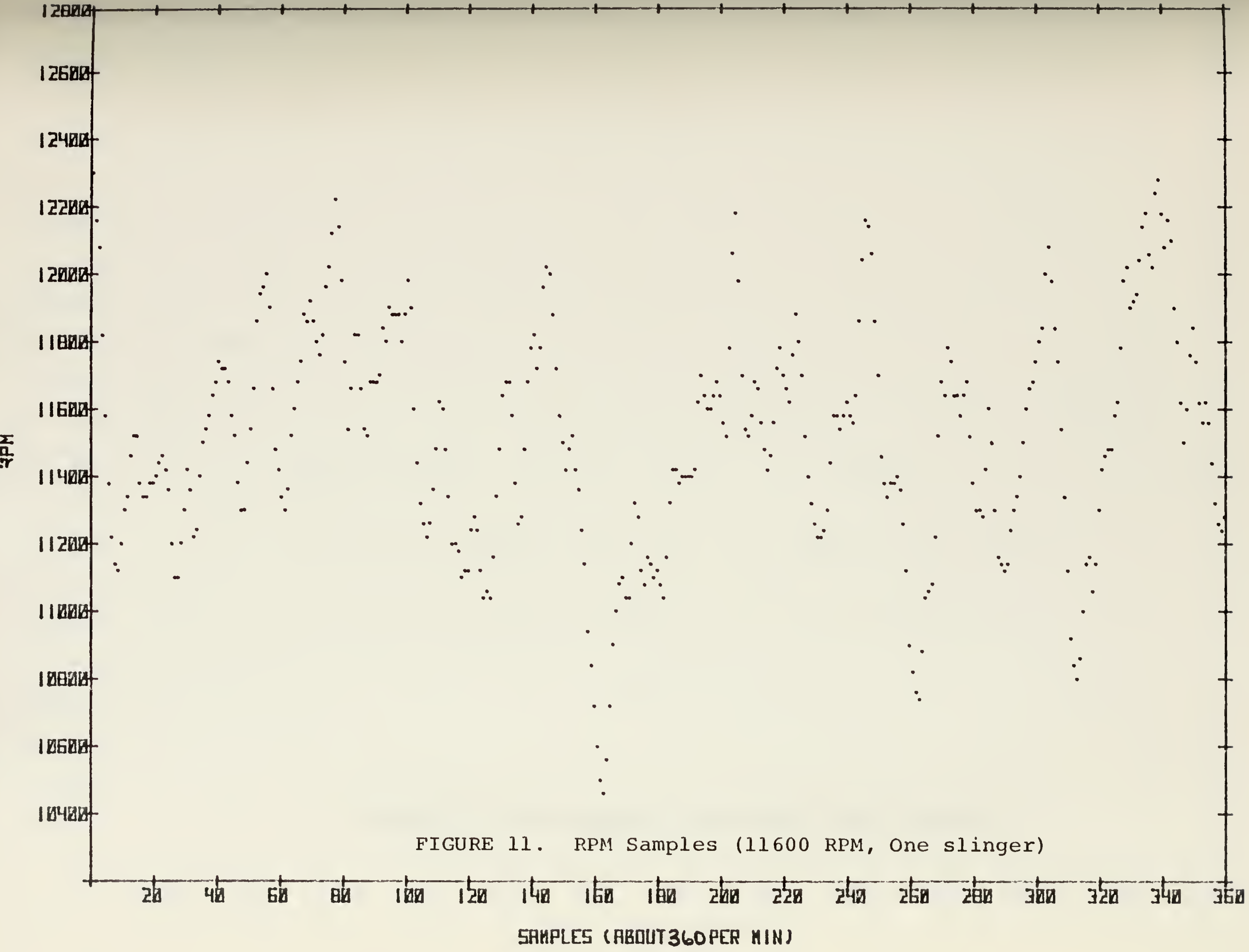


FIGURE 11. RPM Samples (11600 RPM, One slinger)

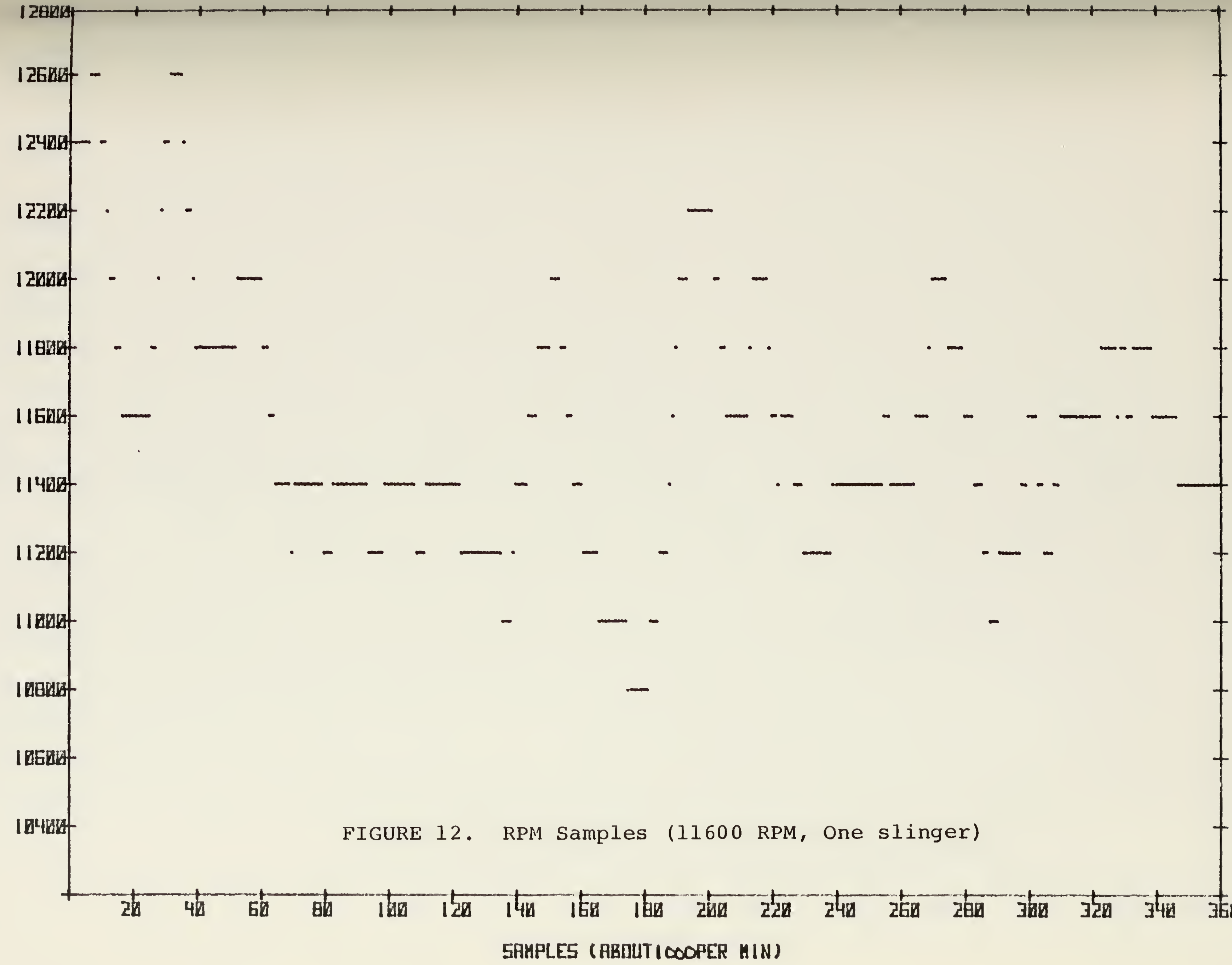


FIGURE 12. RPM Samples (11600 RPM, One slinger)

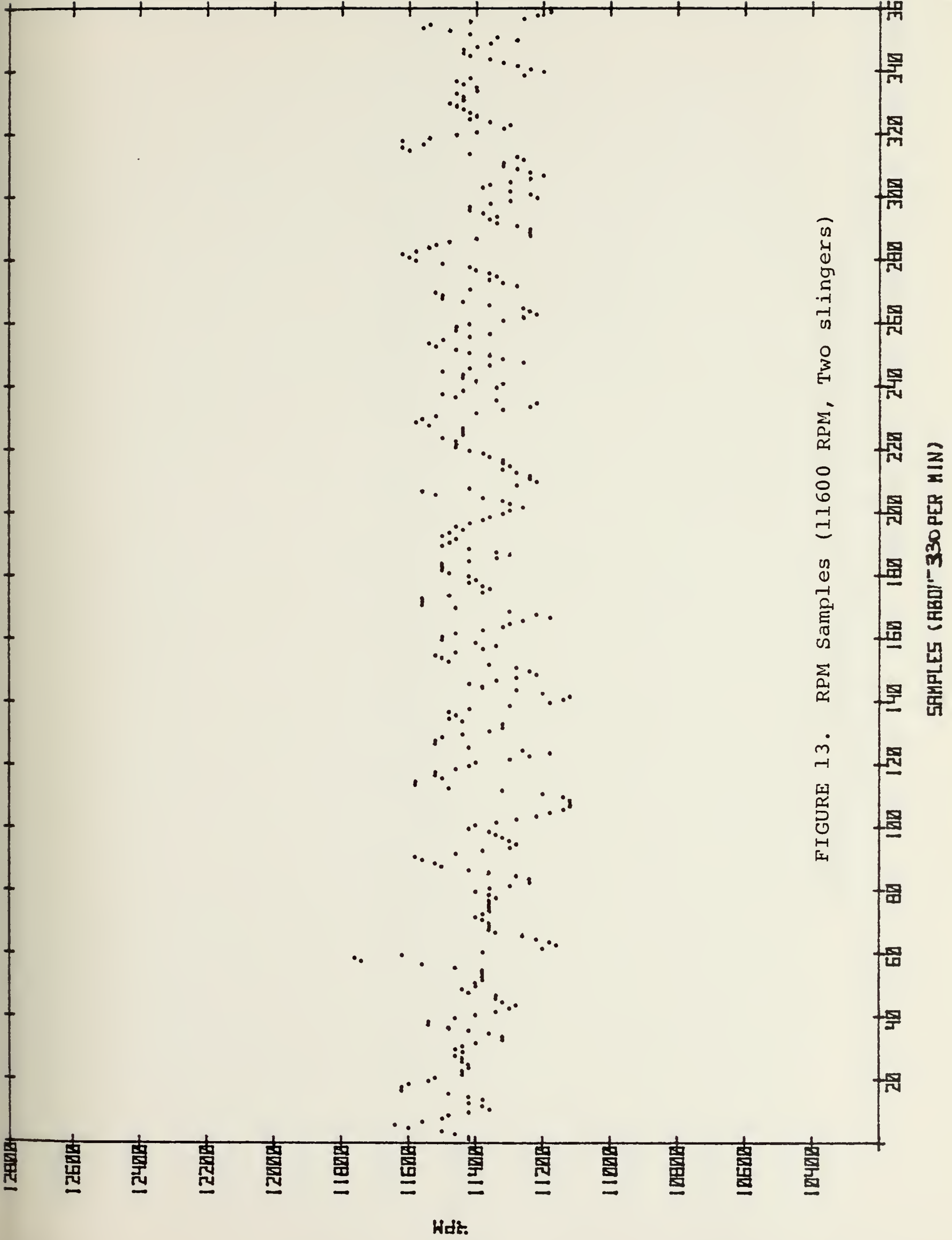


FIGURE 13. RPM Samples (11600 RPM, Two slingers)

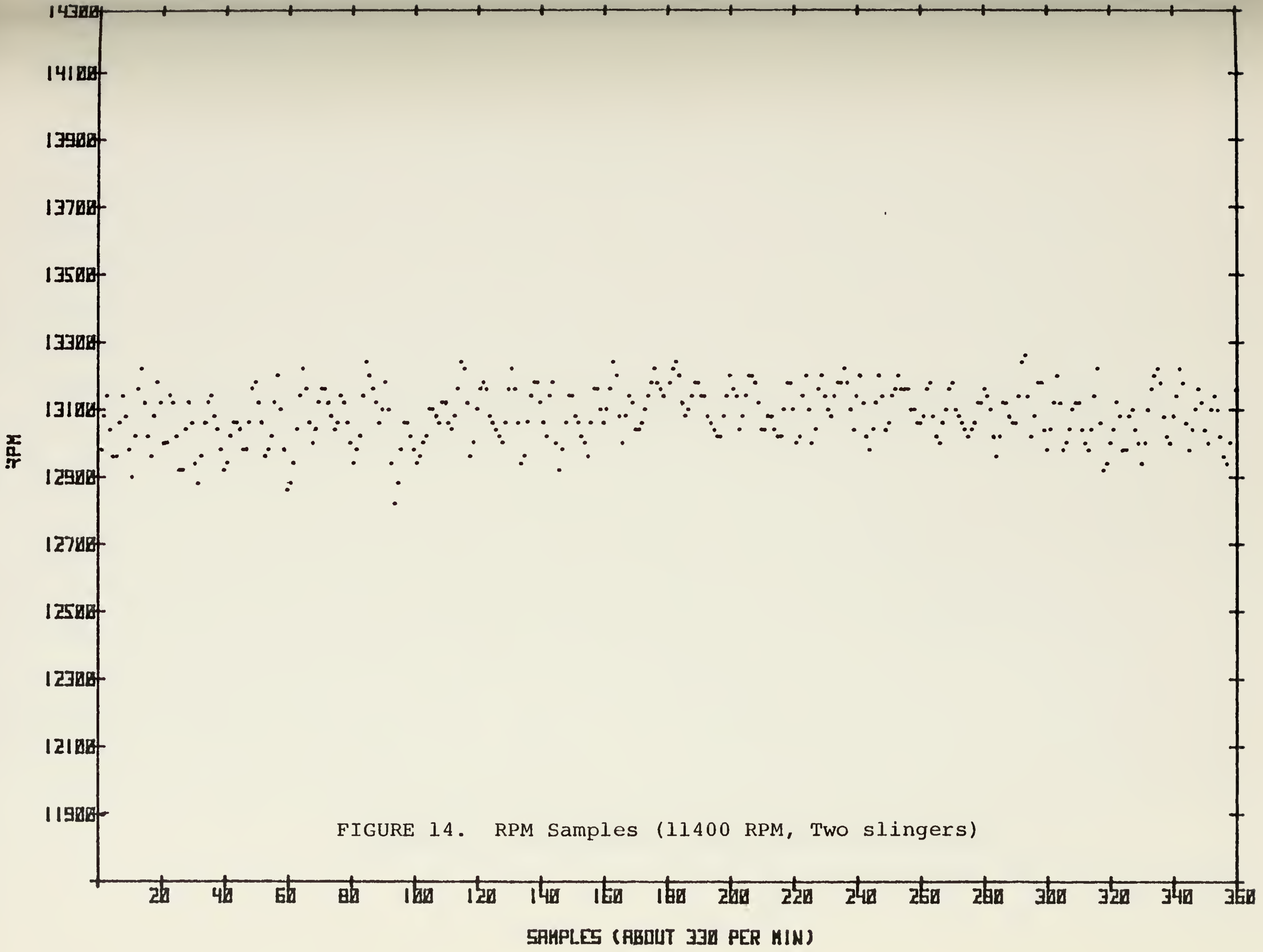


FIGURE 14. RPM Samples (11400 RPM, Two slingers)

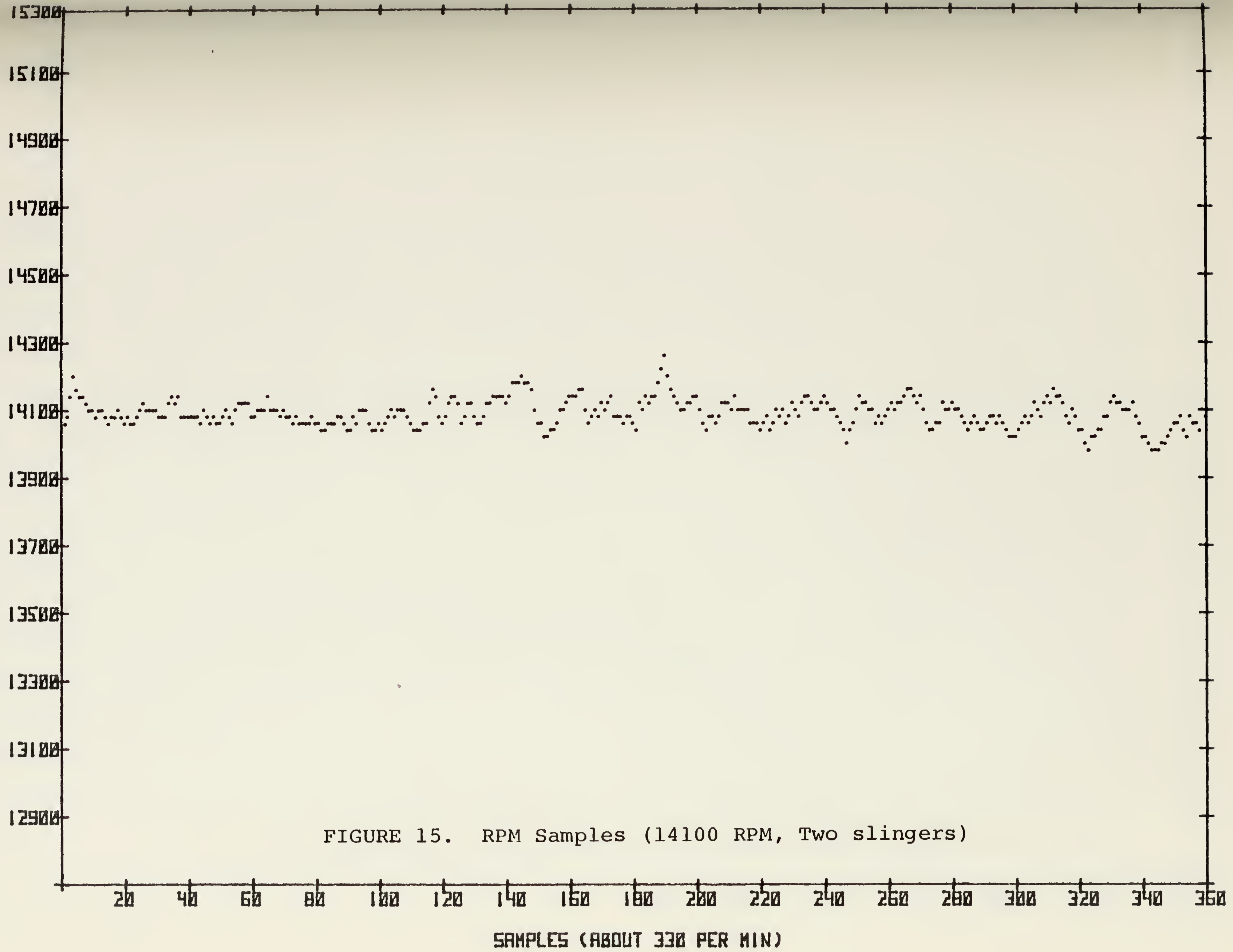


FIGURE 15. RPM Samples (14100 RPM, Two slingers)

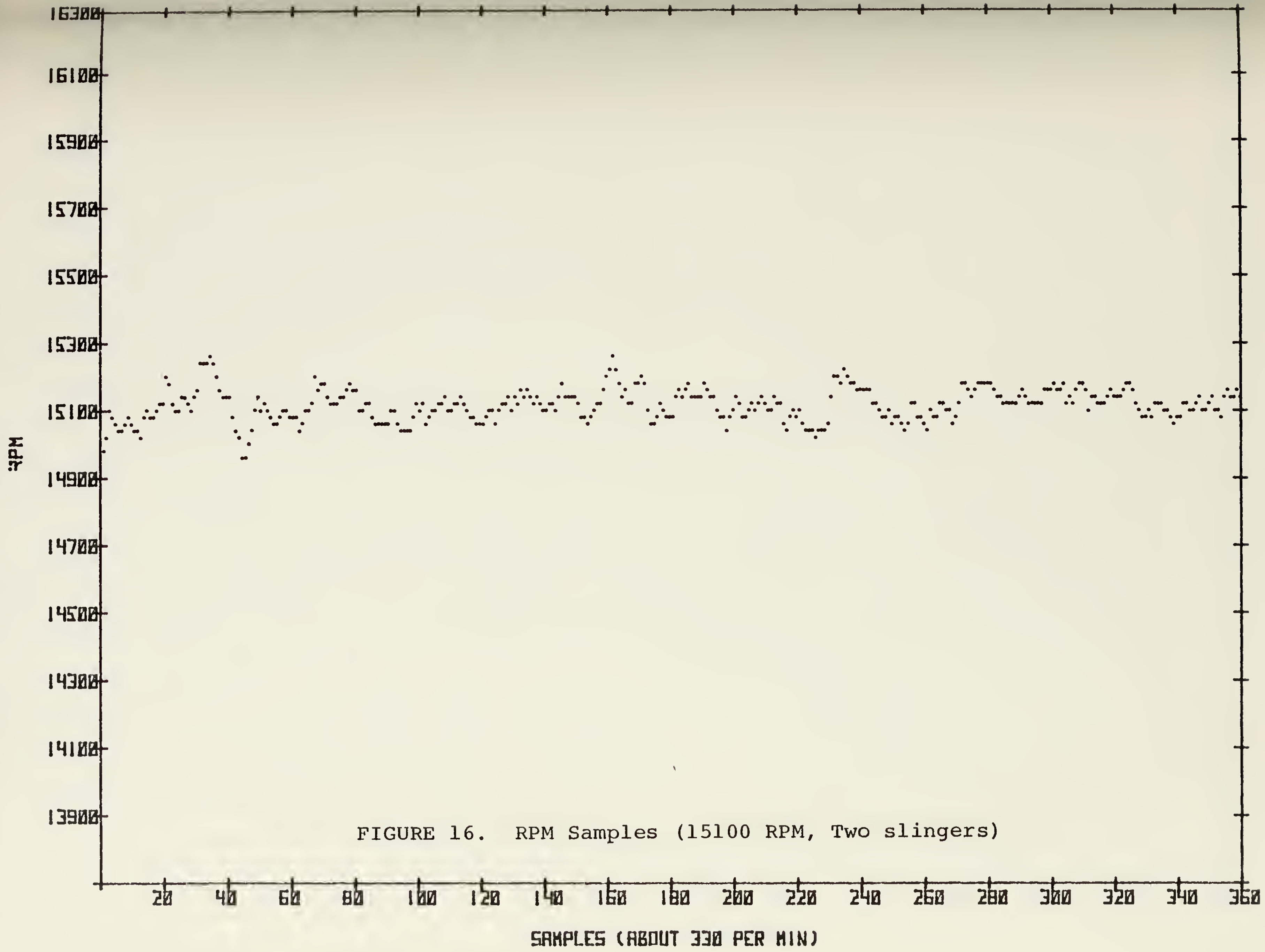


FIGURE 16. RPM Samples (15100 RPM, Two slingers)

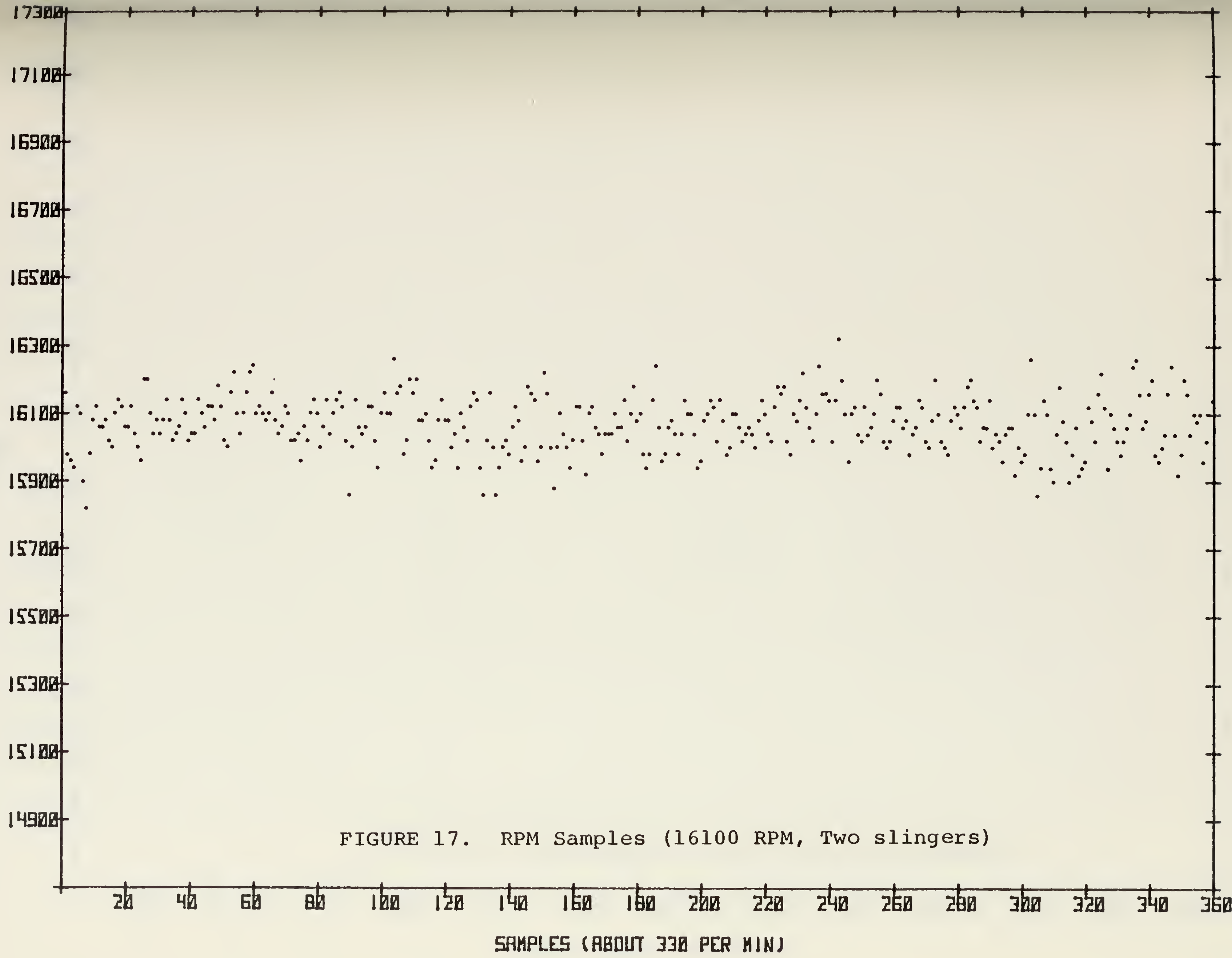


FIGURE 17. RPM Samples (16100 RPM, Two slingers)

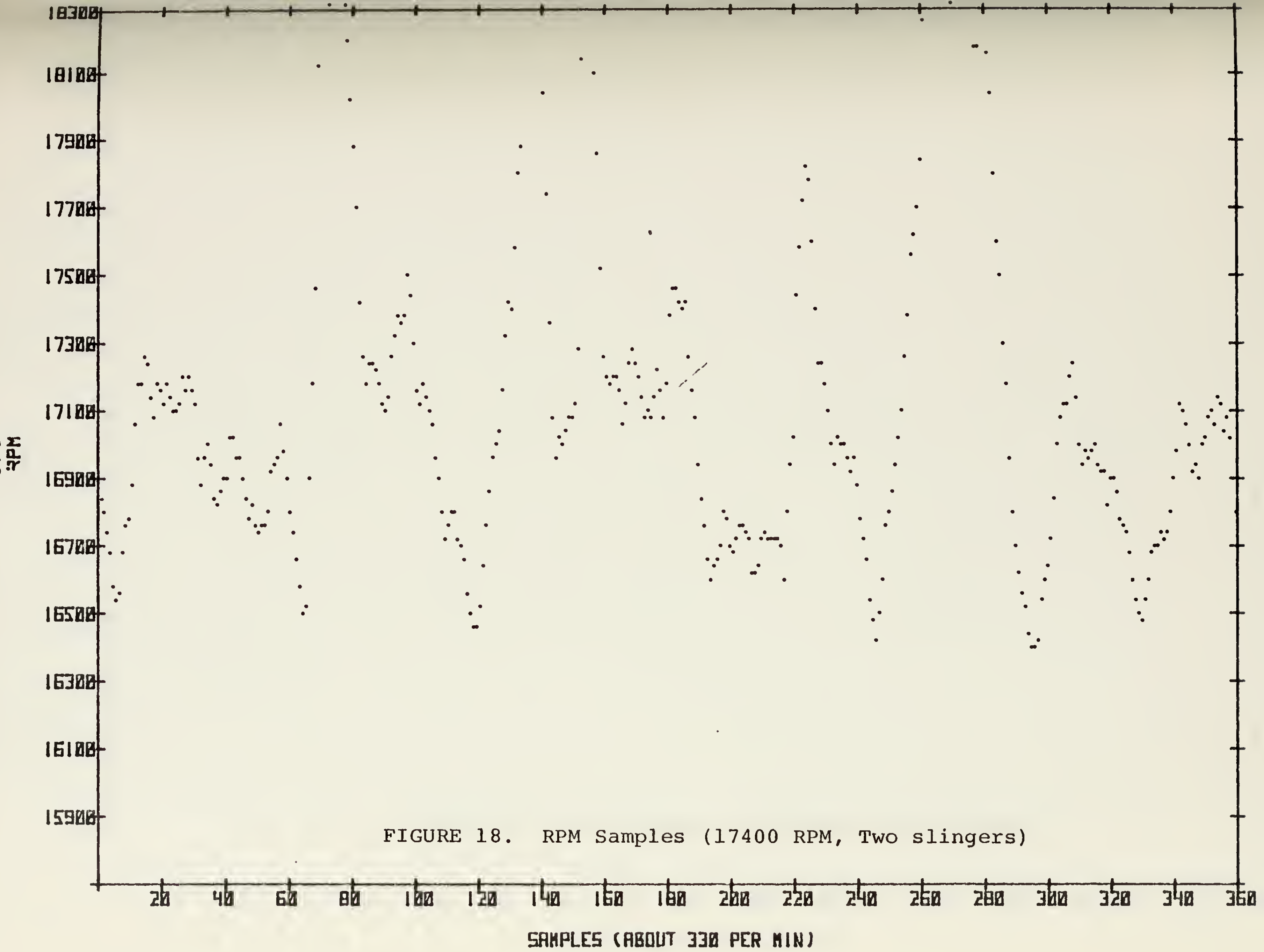


FIGURE 18. RPM Samples (17400 RPM, Two slingers)

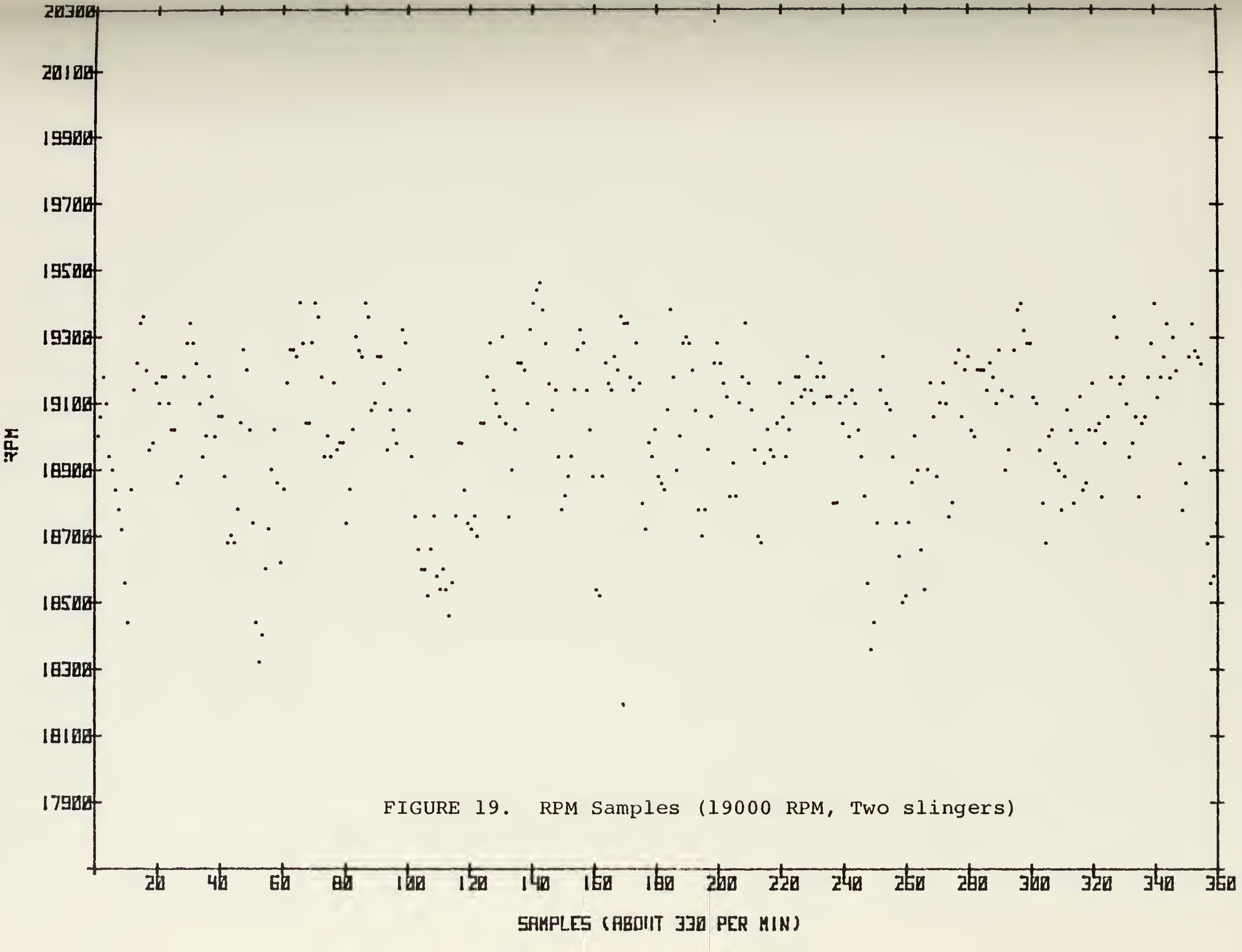


FIGURE 19. RPM Samples (19000 RPM, Two slingers)

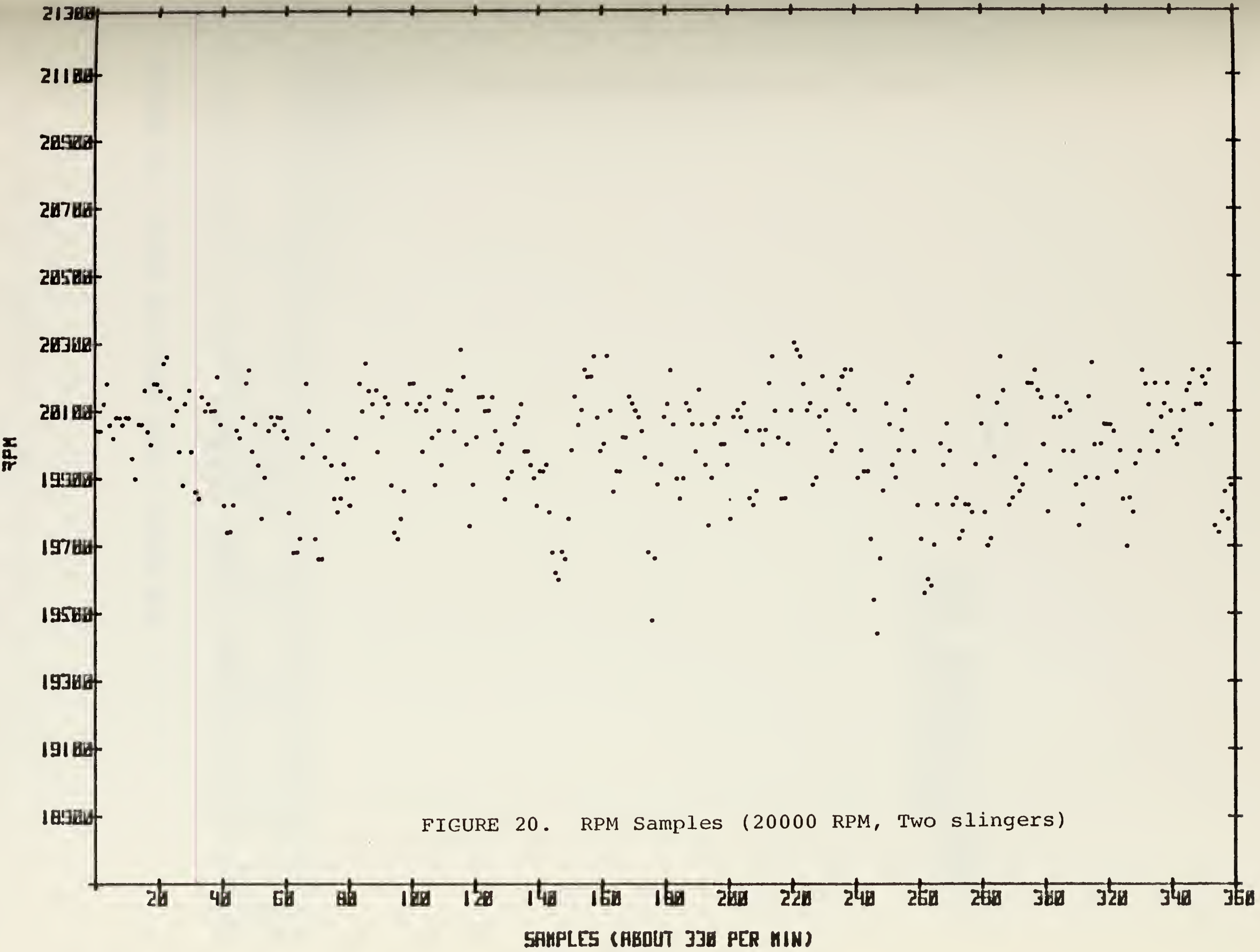


FIGURE 20. RPM Samples (20000 RPM, Two slingers)

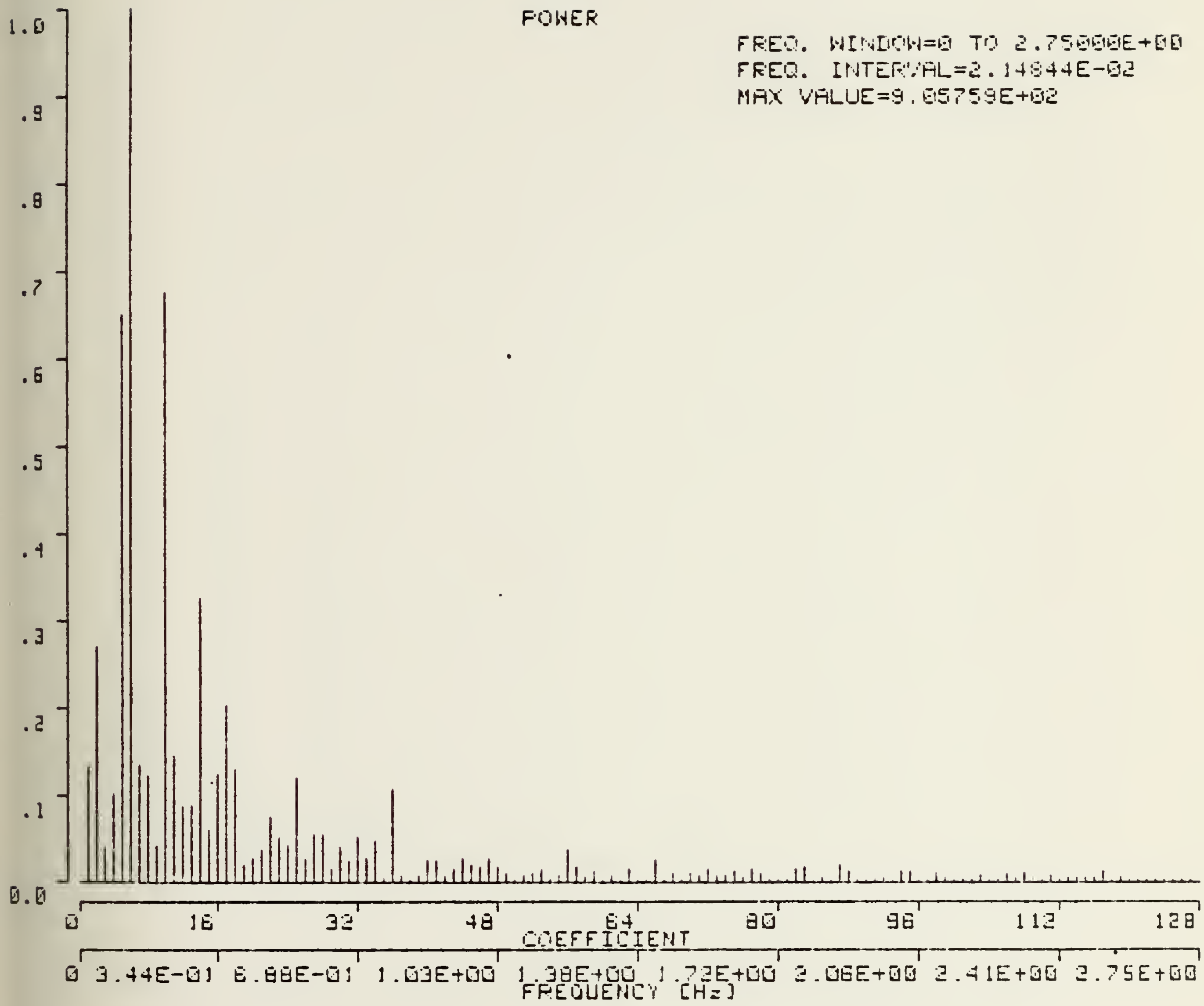


FIGURE 21. POWER SPECTRUM DATA - 15000 RPM

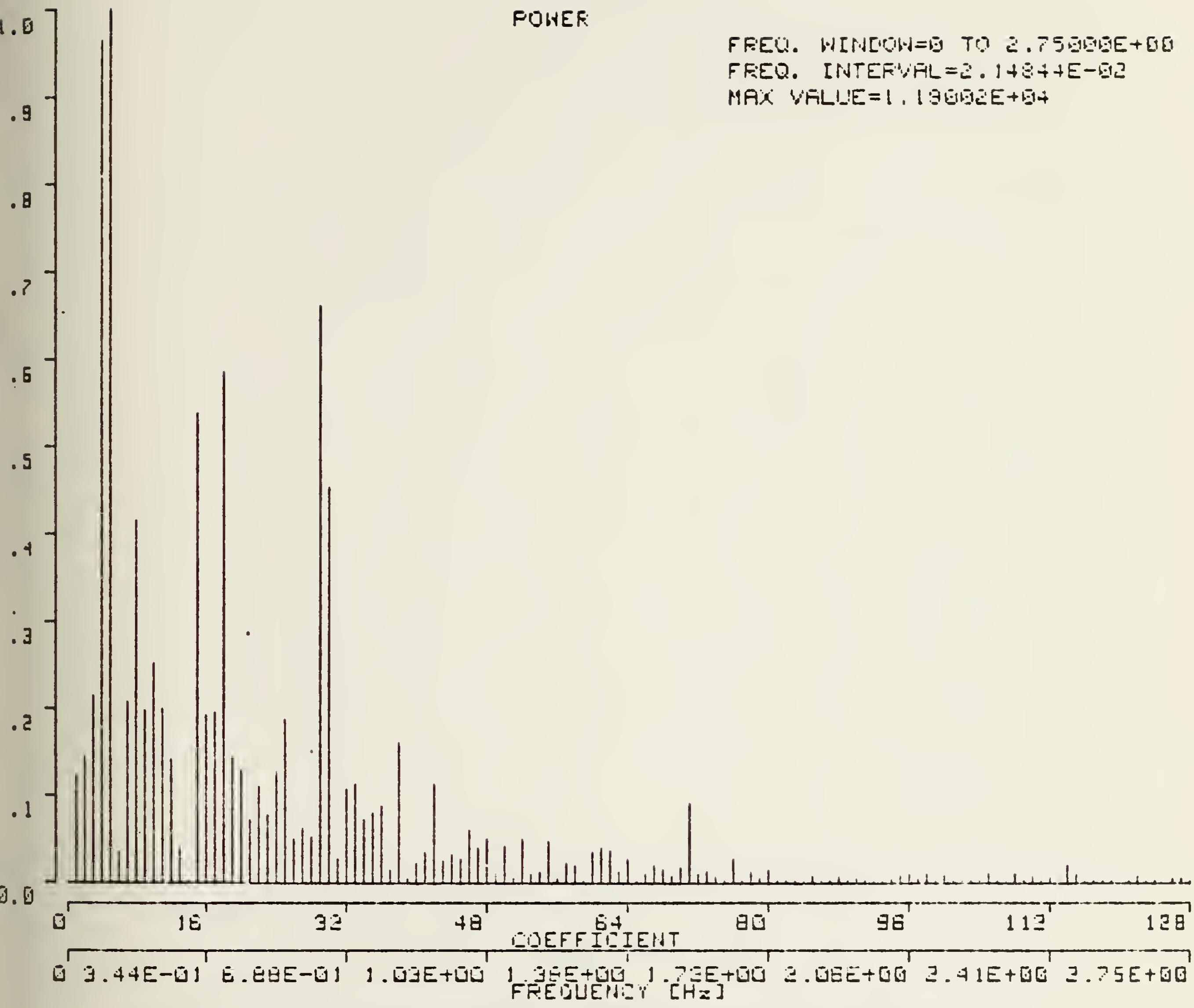


FIGURE 22. POWER SPECTRUM DATA - 19000 RPM

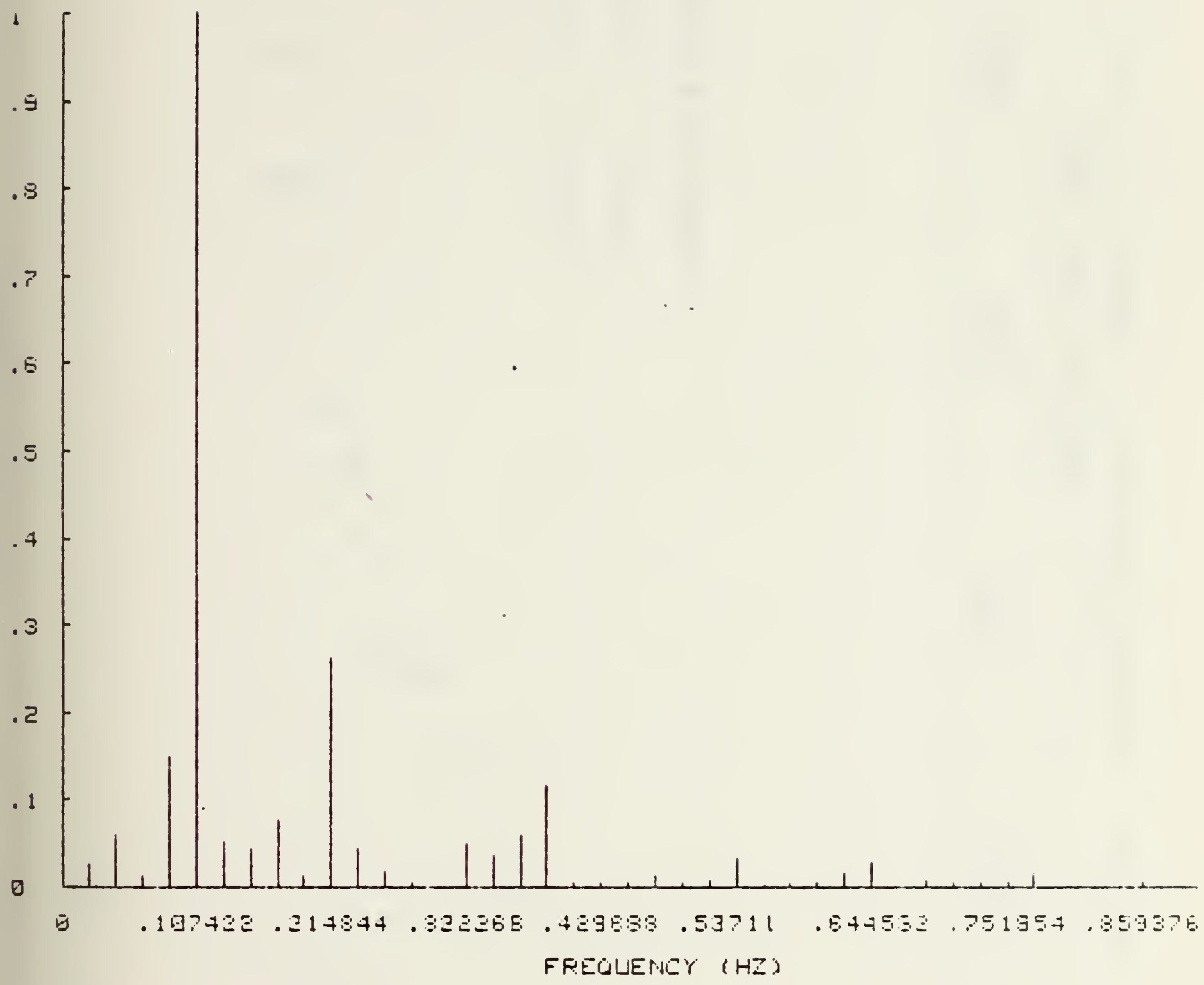


FIGURE 23. POWER SPECTRUM CORRELATION (15000/19000 RPM)

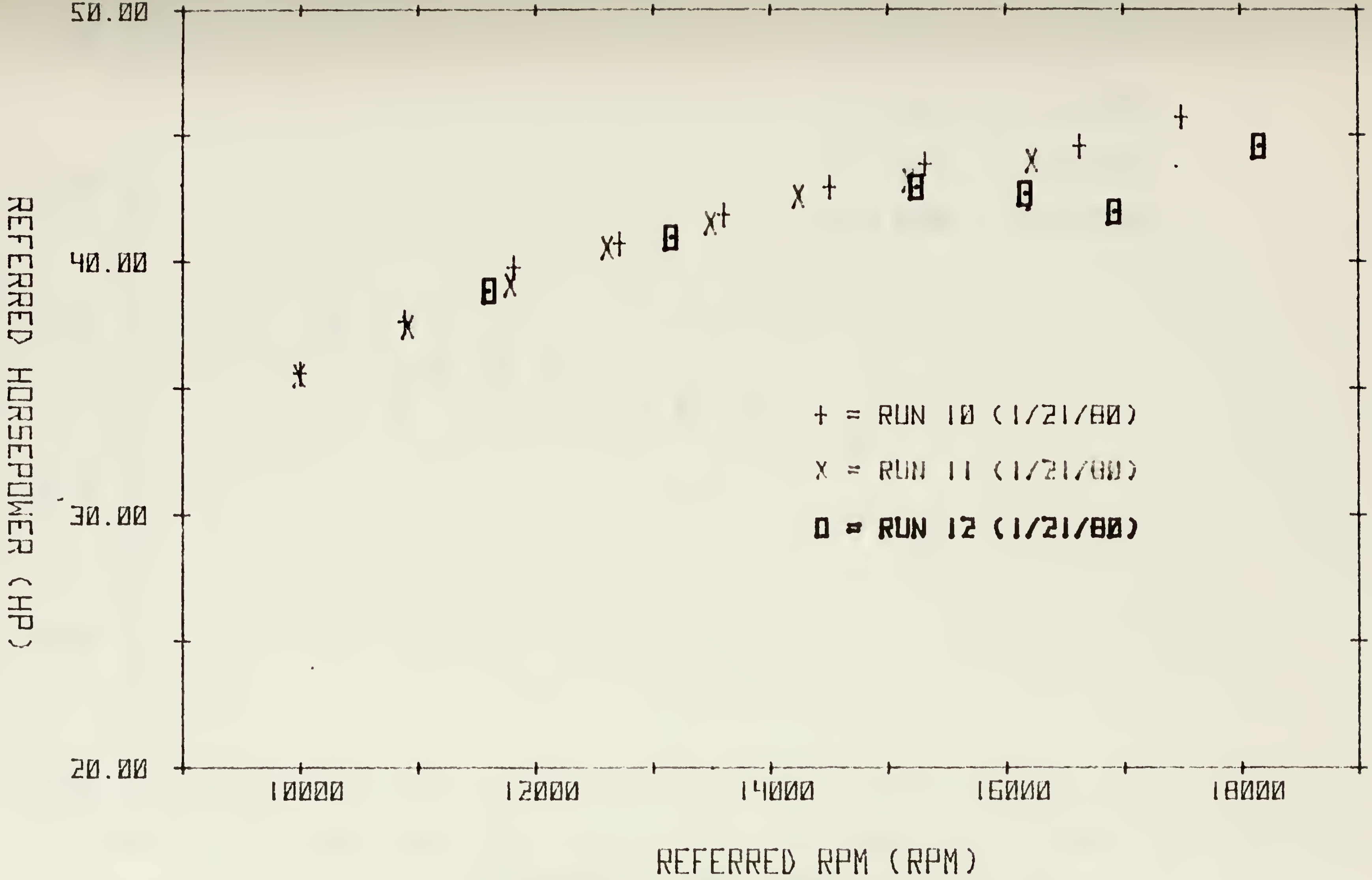


FIGURE 24. REFERRED HORSEPOWER vs. REFERRED RPM (PR=3.5)

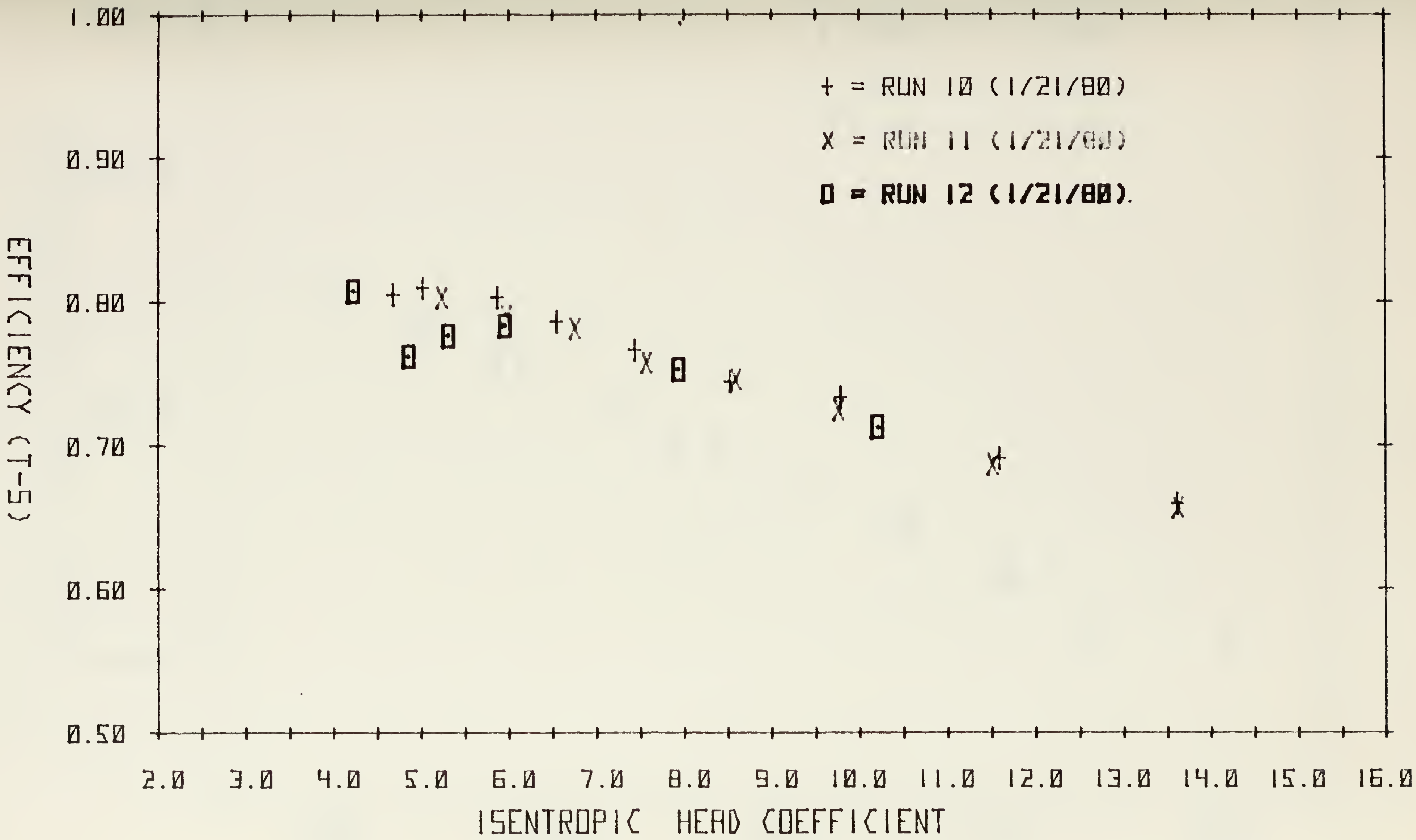


FIGURE 25. EFFICIENCY (T-S) vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5)

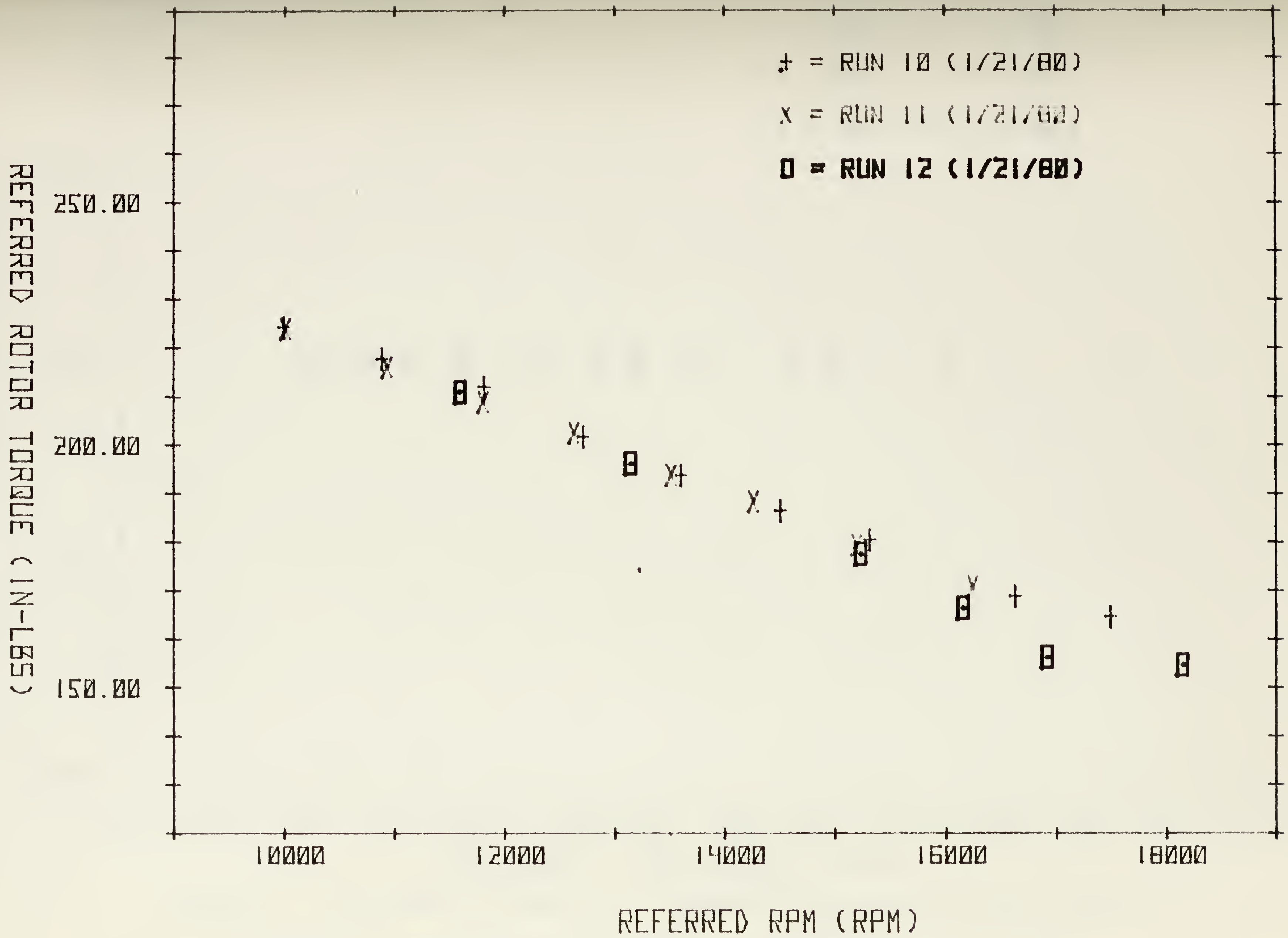


FIGURE 26. REFERRED ROTOR TORQUE vs. REFERRED RPM (PR=3.5)

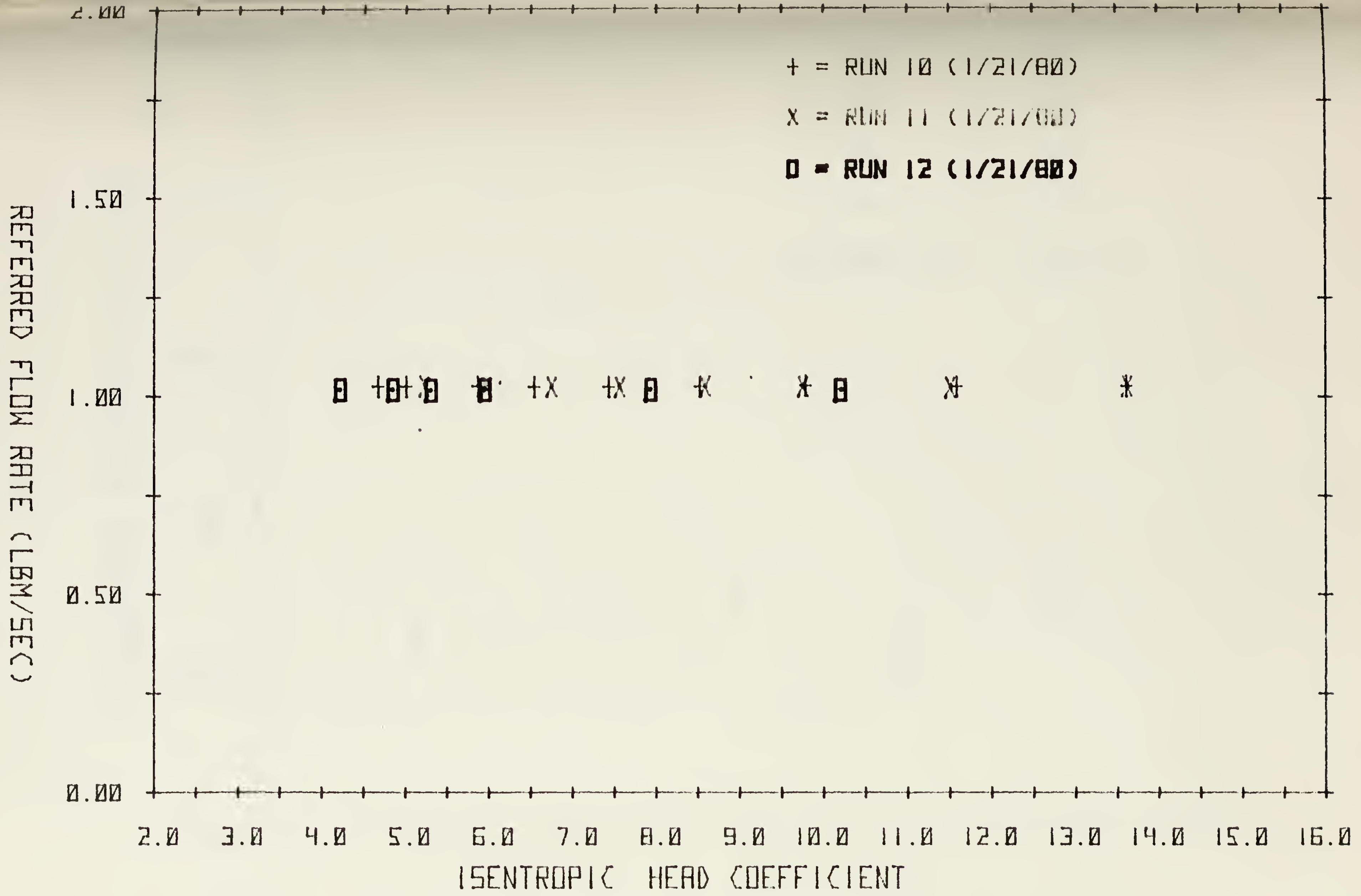


FIGURE 27. REFERRED FLOW RATE vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5)

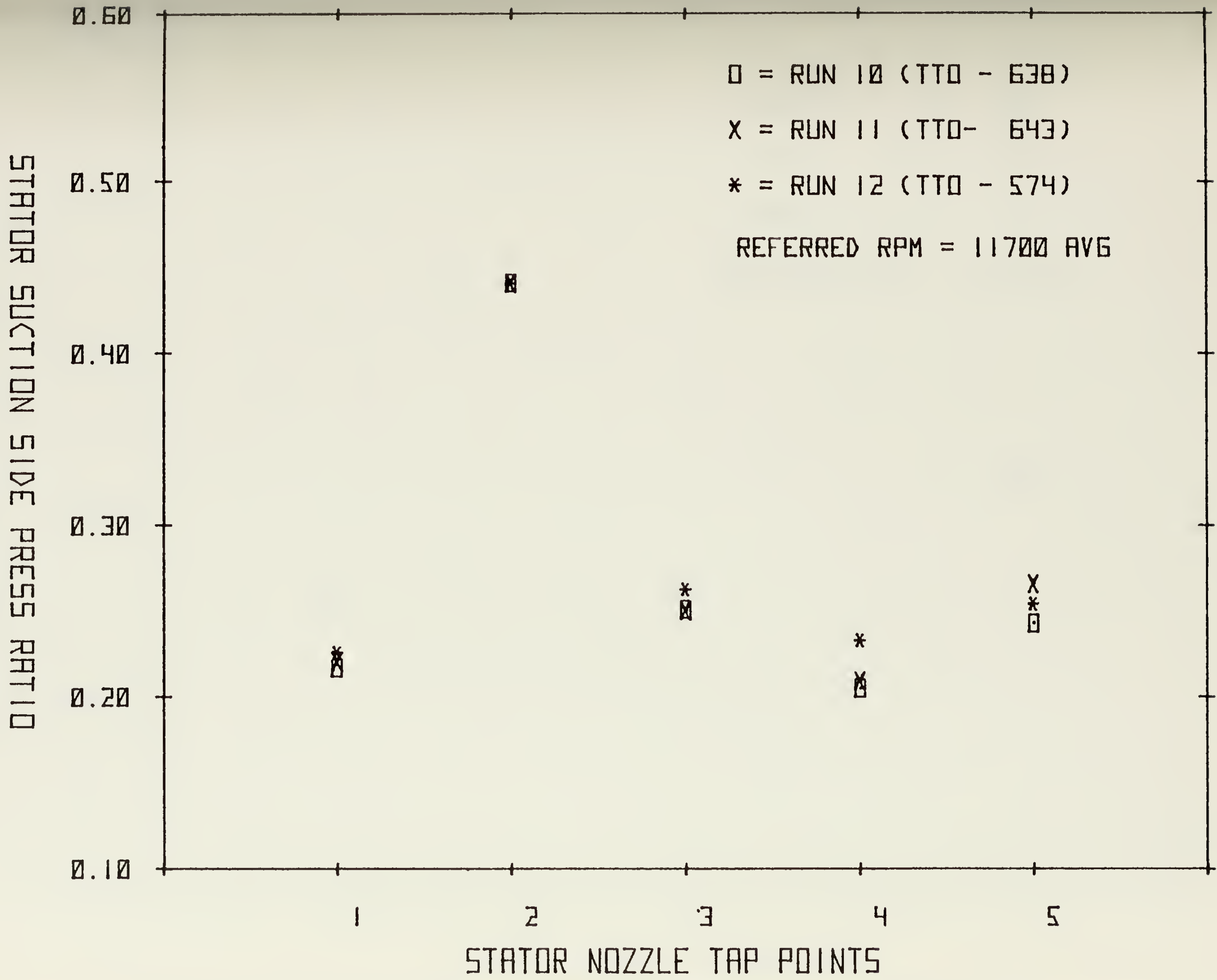


FIGURE 28. STATOR SUCTION SIDE PRESSURE RATIO vs. STATOR NOZZLE TAP POINTS - 11700 Referred RPM, PR=3.5

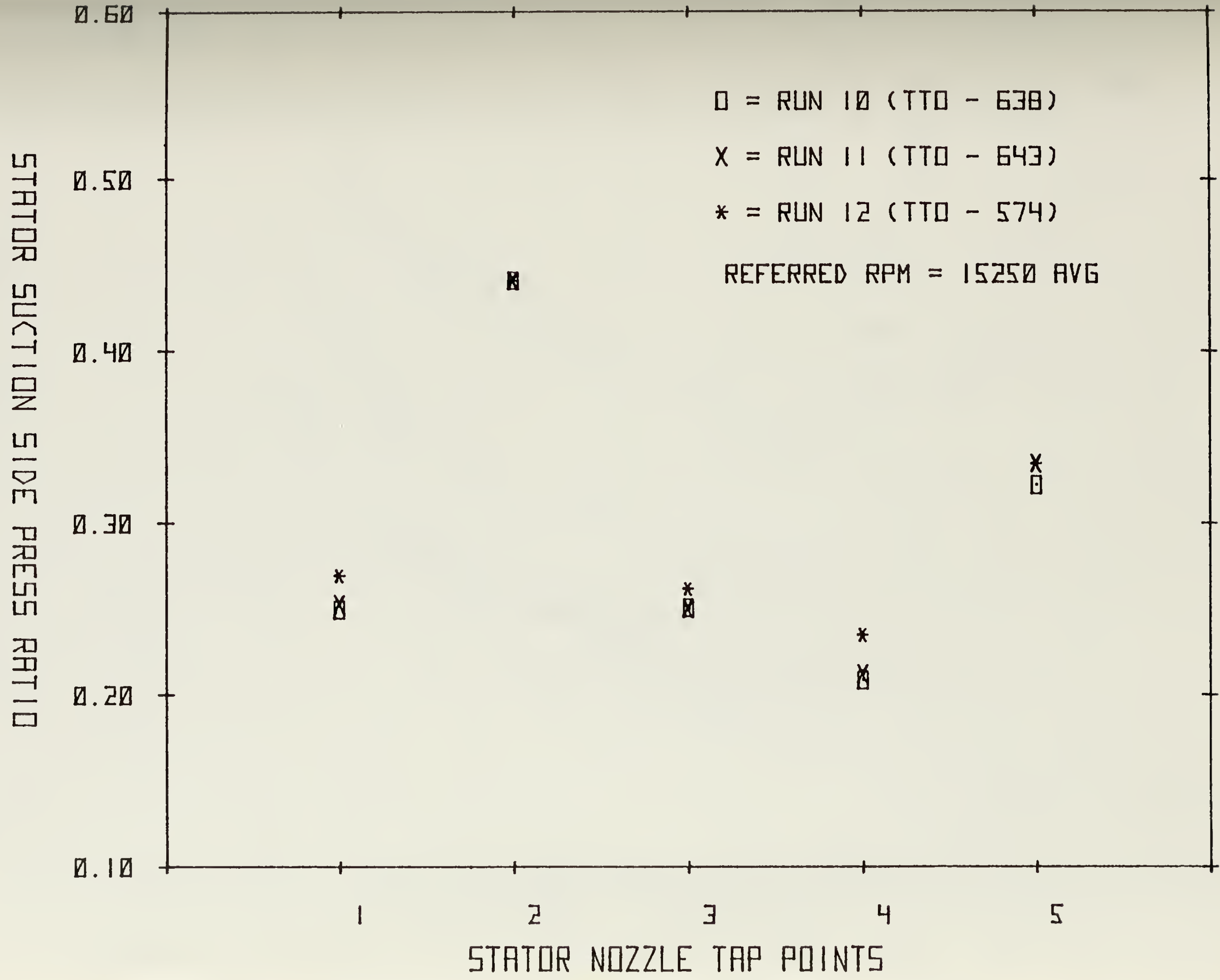


FIGURE 29. STATOR SUCTION SIDE PRESSURE RATIO vs. STATOR NOZZLE TAP POINTS - 15250 Referred RPM, PR=3.5

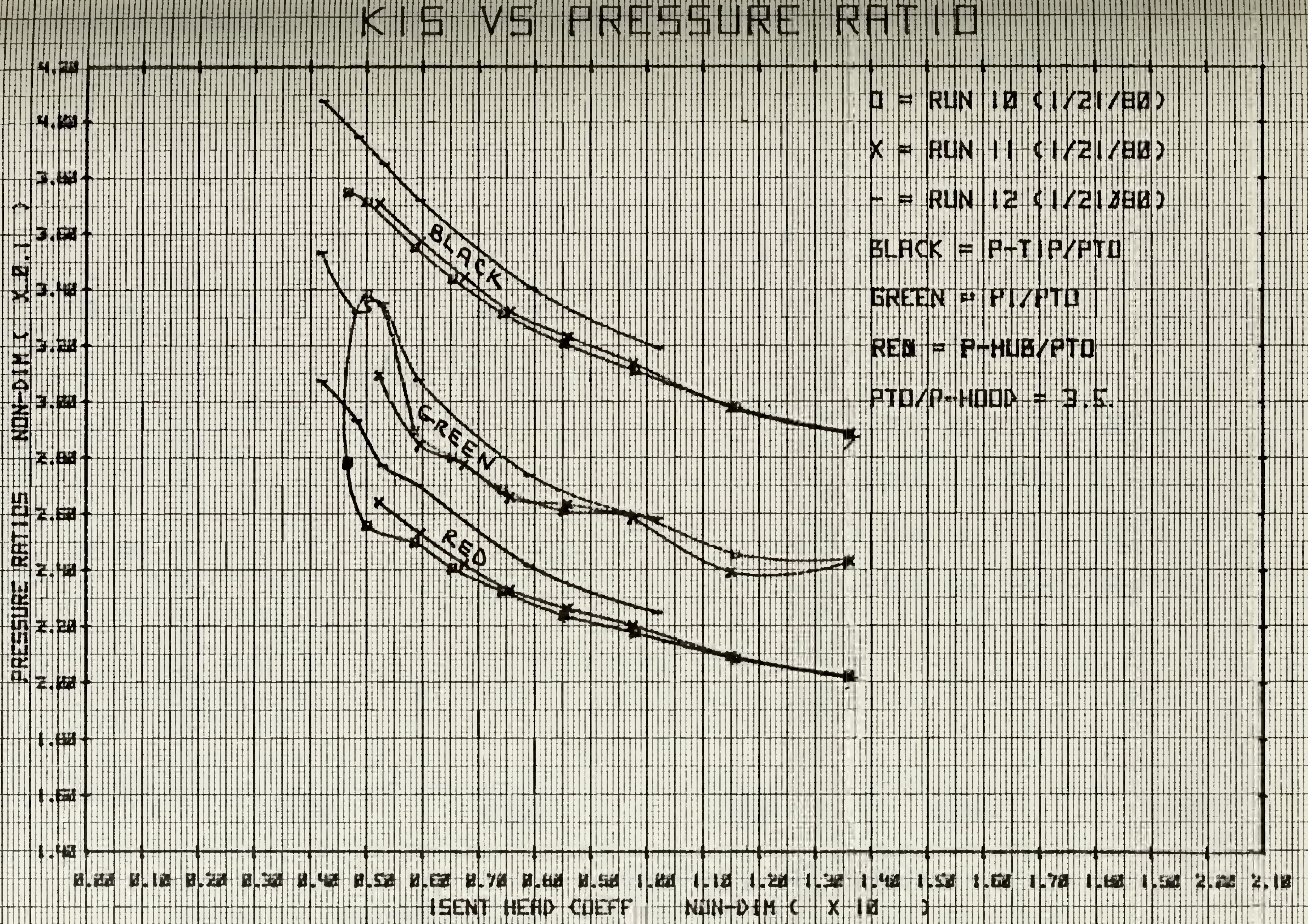


FIGURE 30. PRESSURE RATIO vs. ISENTROPIC HEAD COEFFICIENT

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO. MADE IN U.S.A.
461510

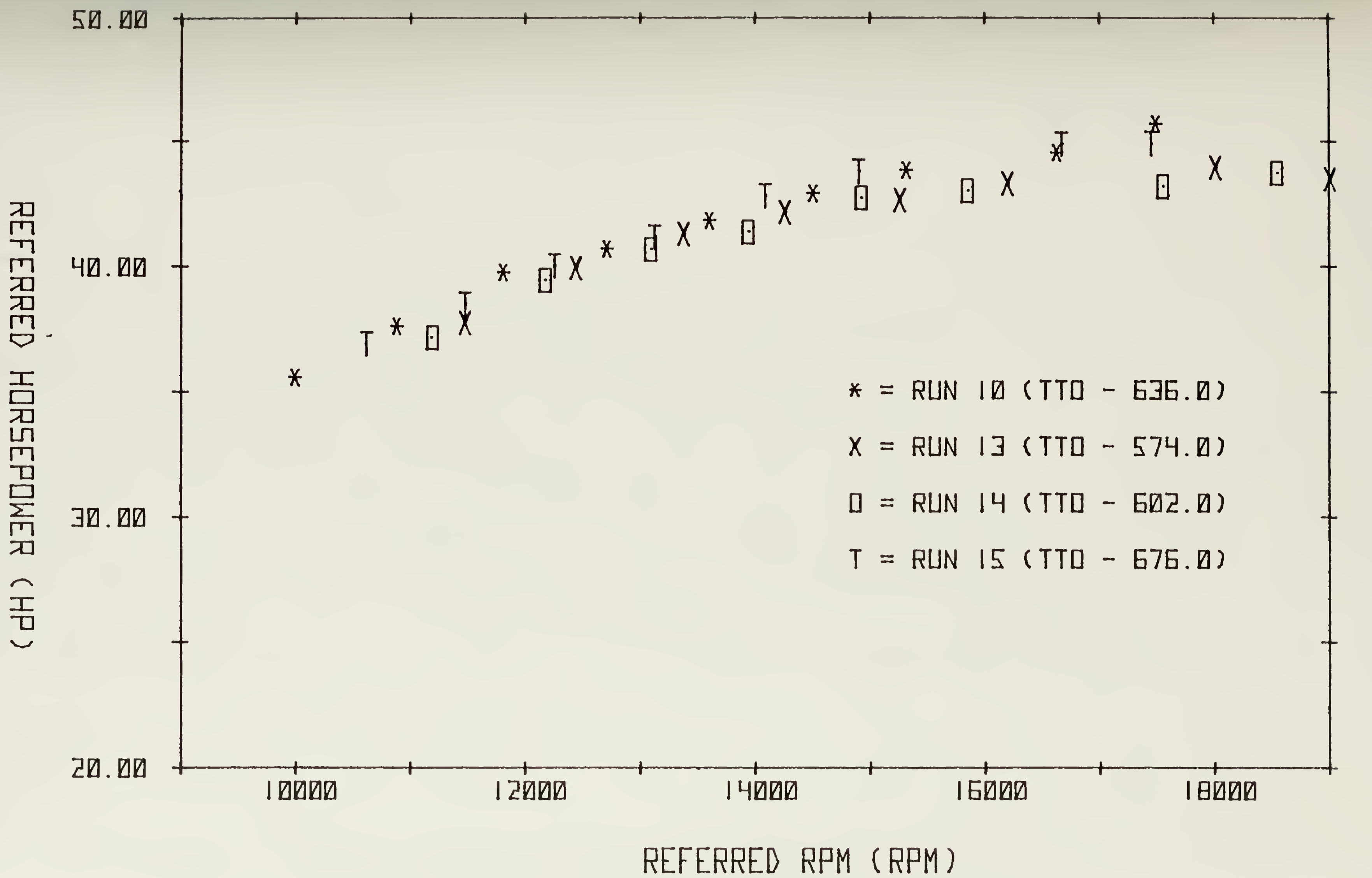


FIGURE 31. REFERRED HP vs. REFERRED RPM (PR=3.5, $P_{t_o}$=60 in Hg)

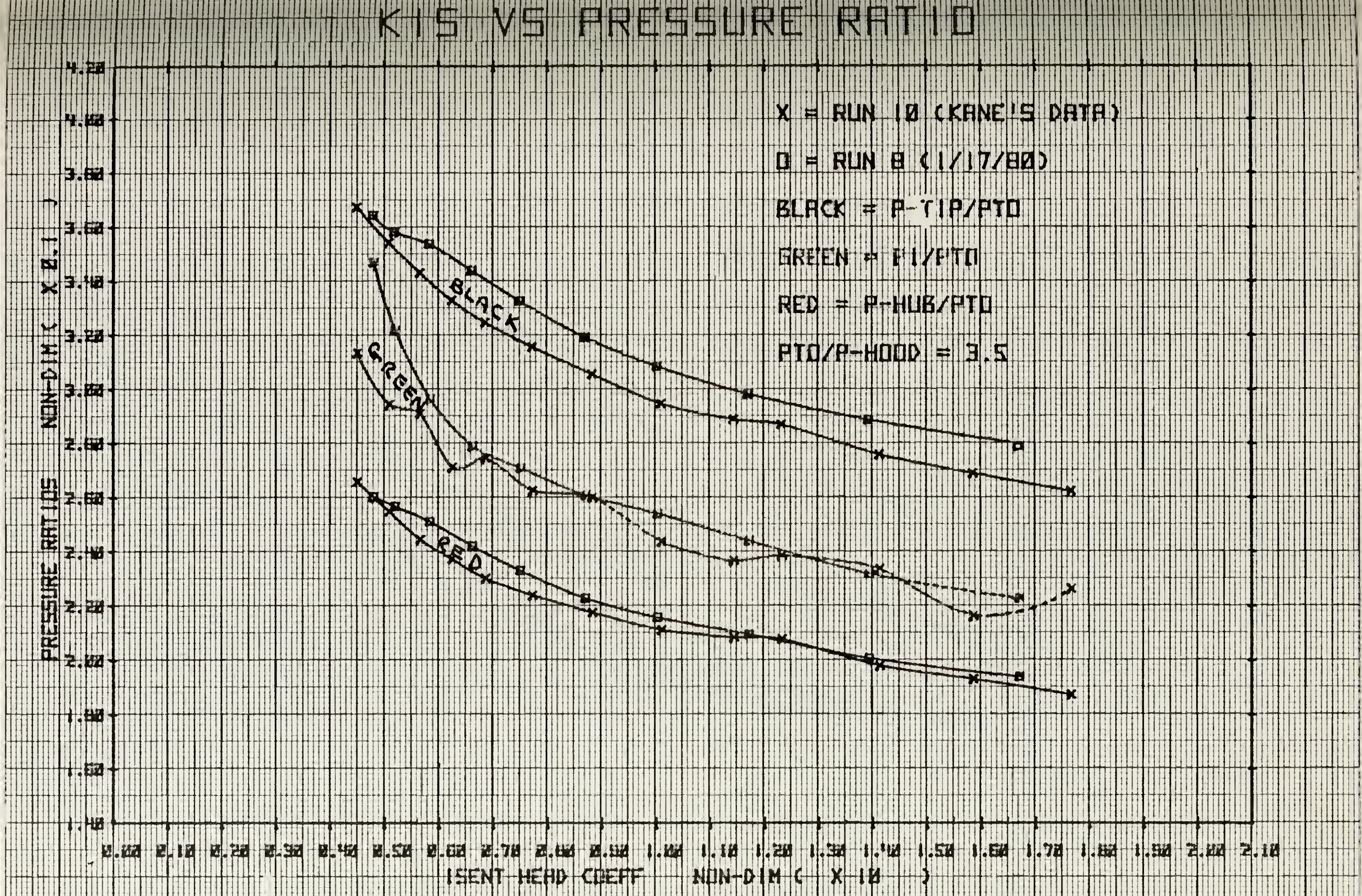


FIGURE 32. PRESSURE RATIO vs. ISENTROPIC HEAD COEFFICIENT
(PR=3.5, $Pt_o$=60 in Hg)

461510
K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO. MADE IN U.S.A.

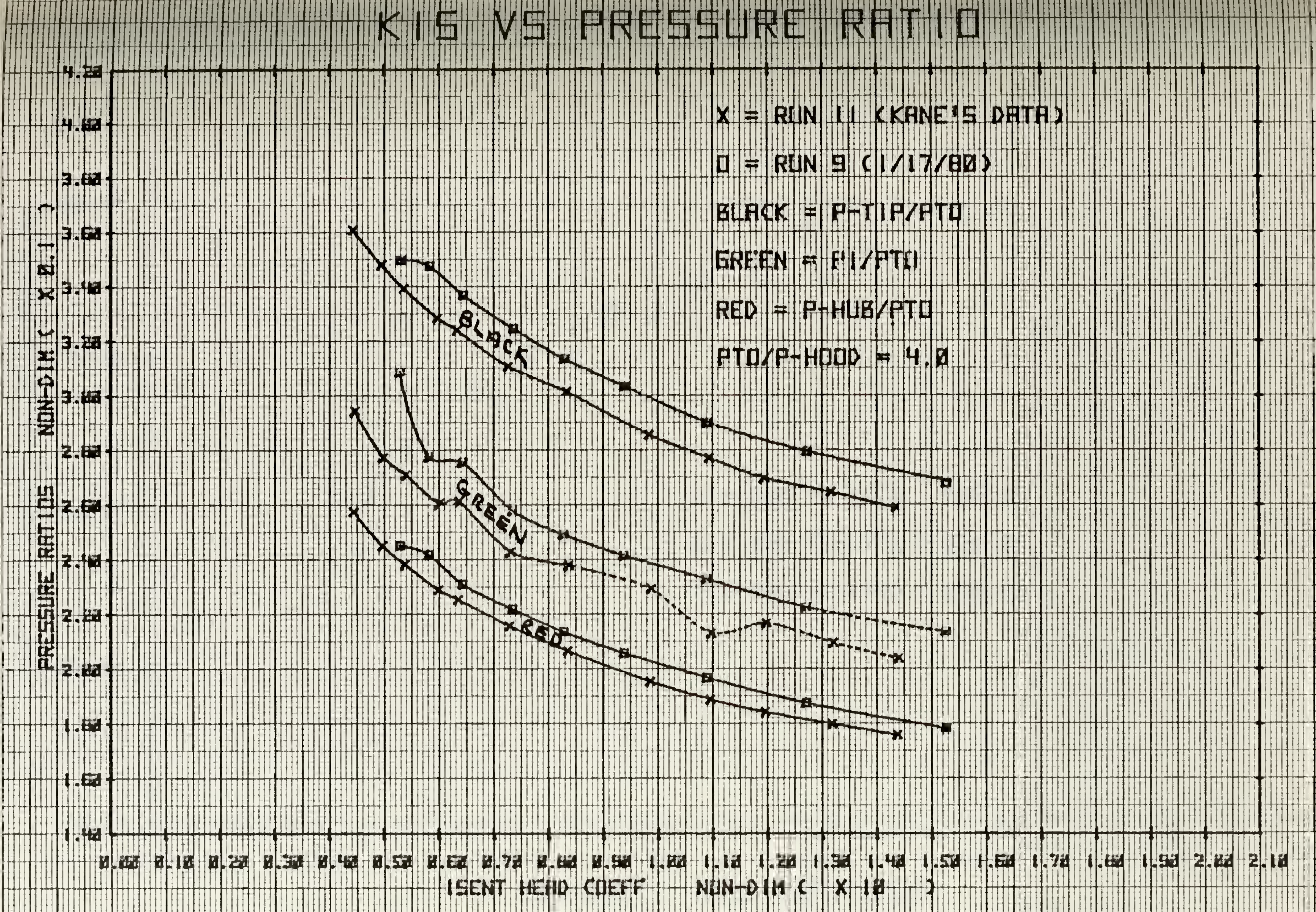


FIGURE 33. PRESSURE RATIO vs. ISENTROPIC HEAD COEFFICIENT (PR=4.0, $Pt_o$=60 in Hg)

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO. MADE IN U.S.A.
461510

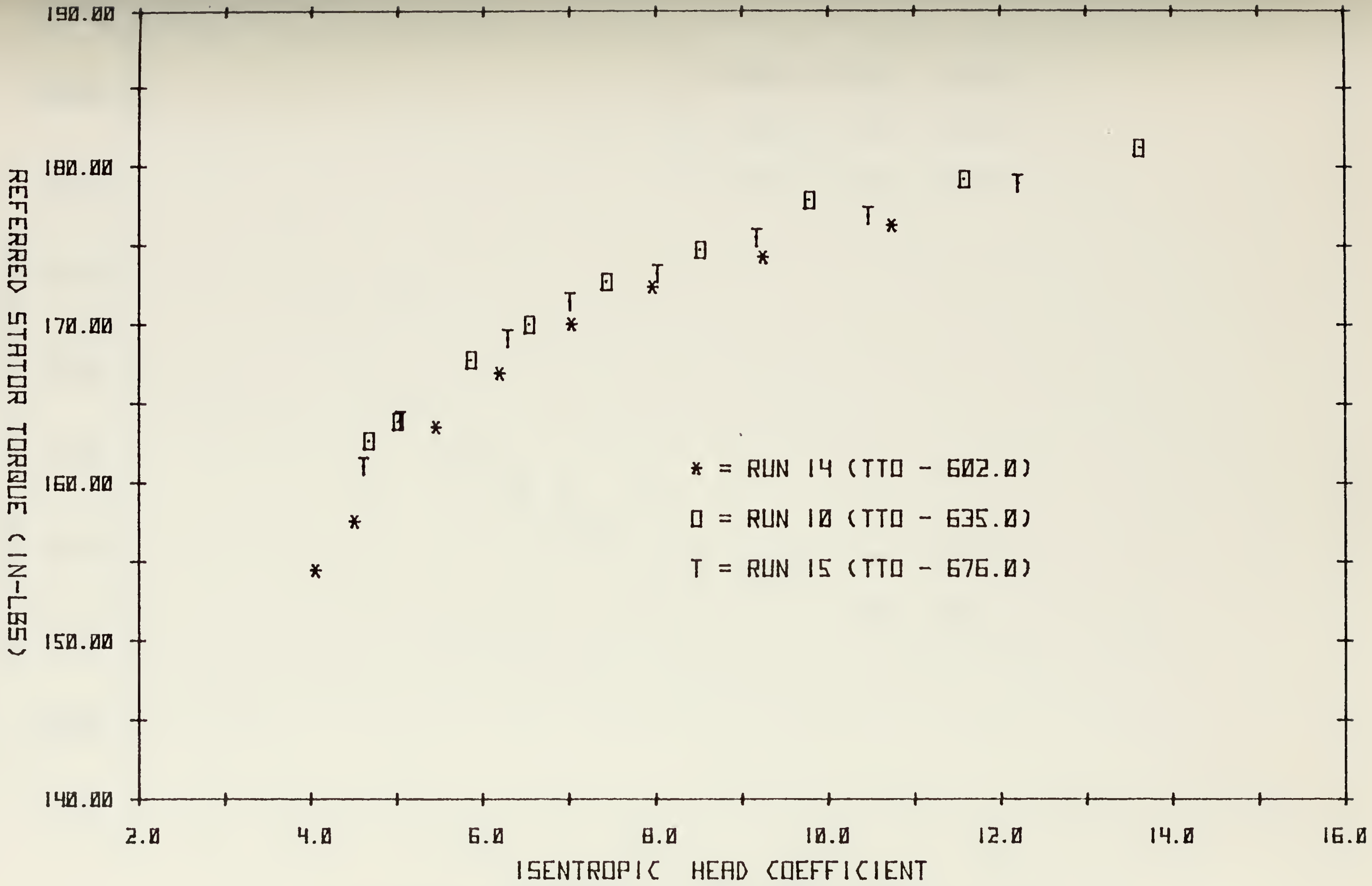


FIGURE 34. REFERRED STATOR TORQUE vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, $P_{t_o}$=60 in Hg)

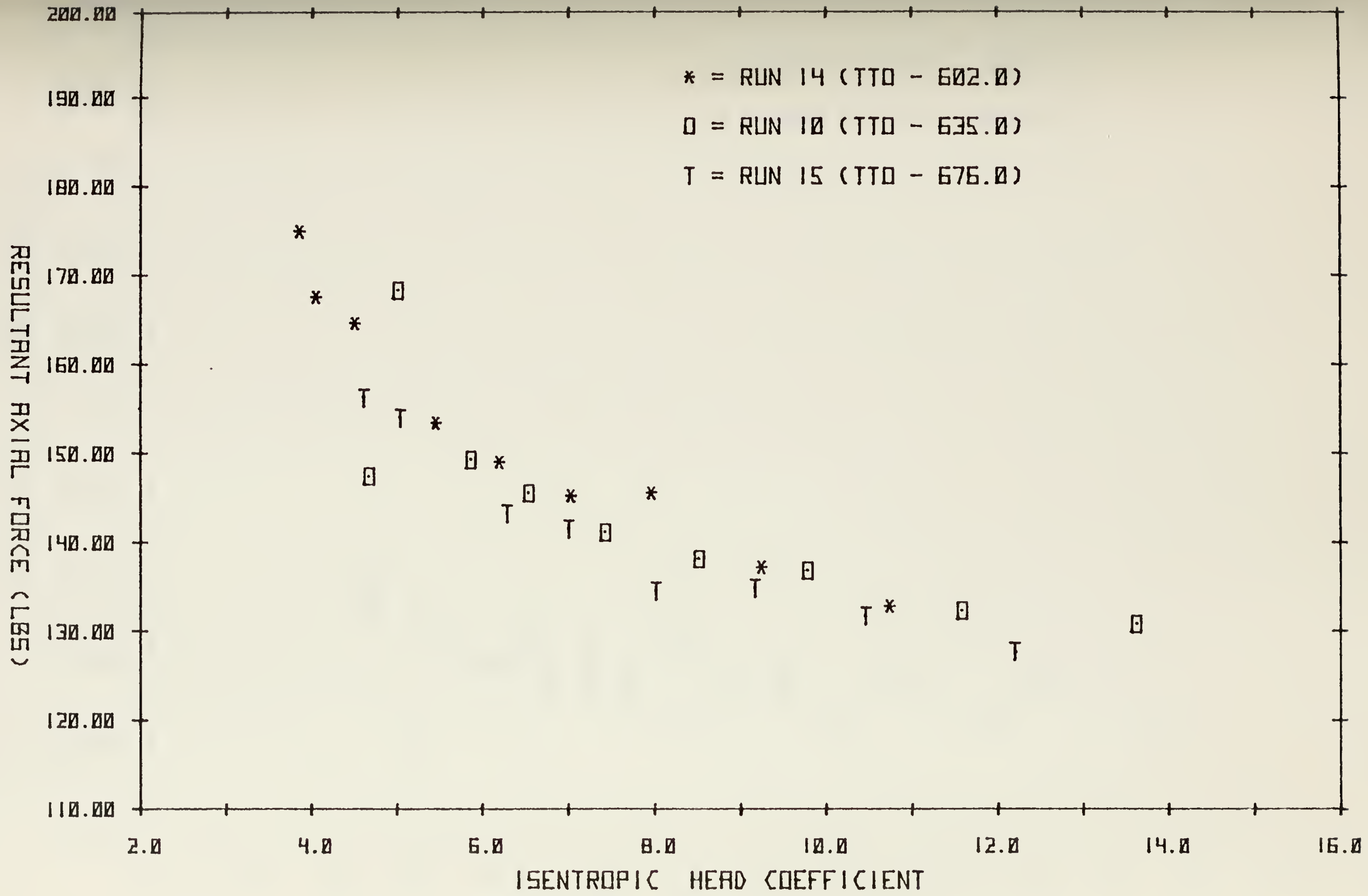


FIGURE 35. RESULTANT AXIAL FORCE vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, $P_{t_o}$=60 in Hg)

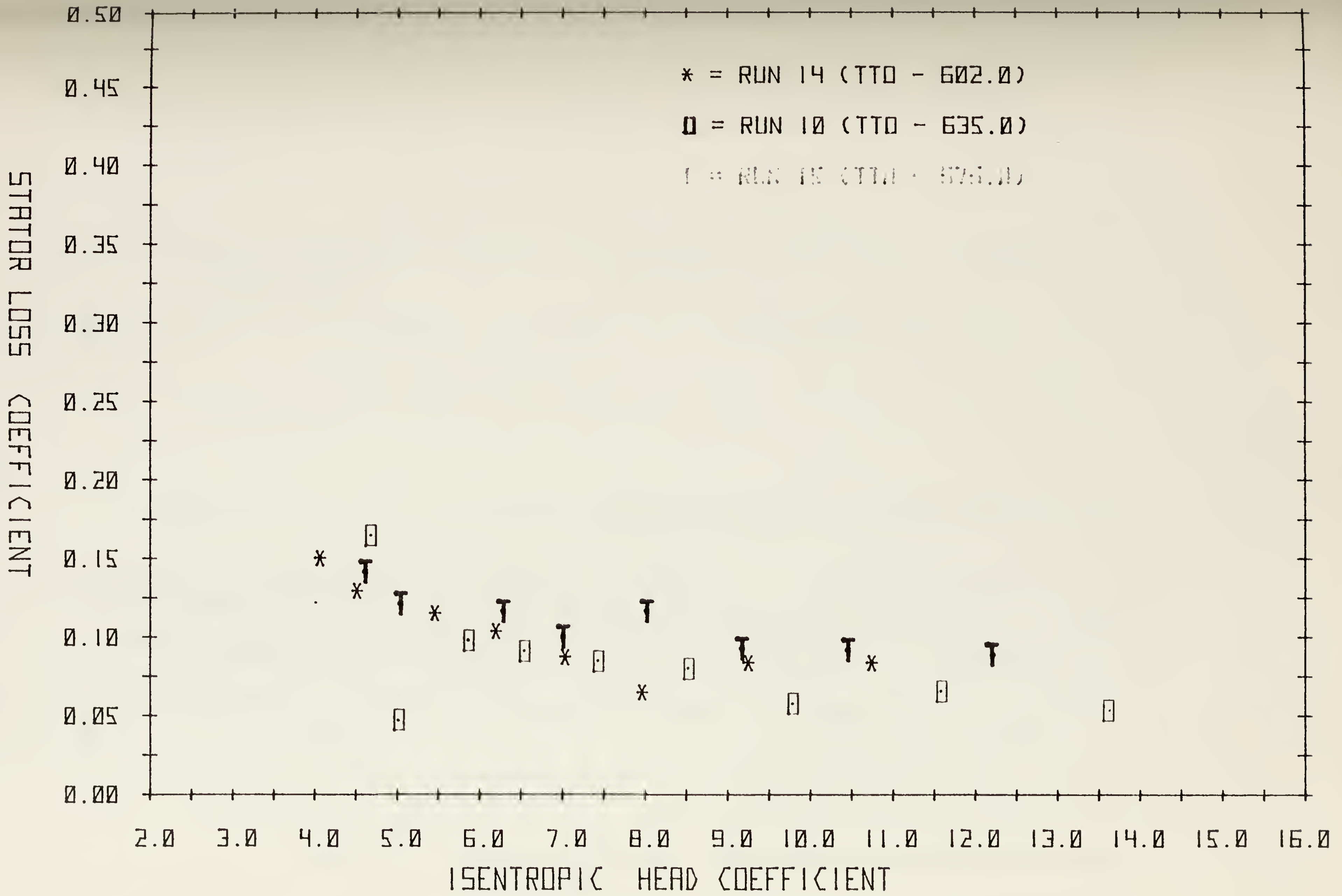


FIGURE 36. STATOR LOSS COEFFICIENT vs. ISENTROPIC HEAD COEFFICIENT ($PR=3.5$, $P_{t_o}=60$ in Hg)

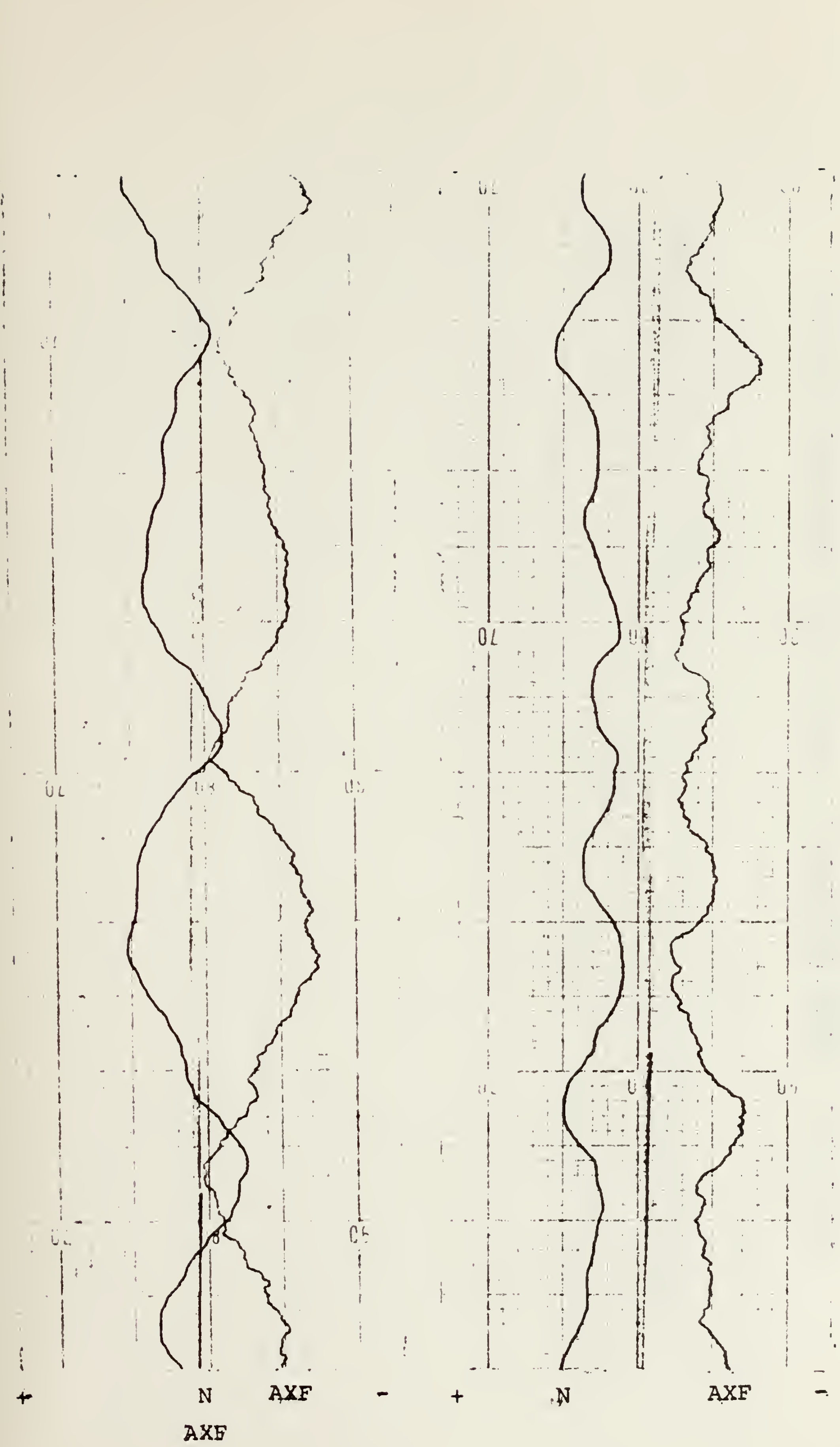


FIGURE 37. ANALOG RECORDING - AXIAL FORCE VARIATION WITH RPM (16000 RPM)

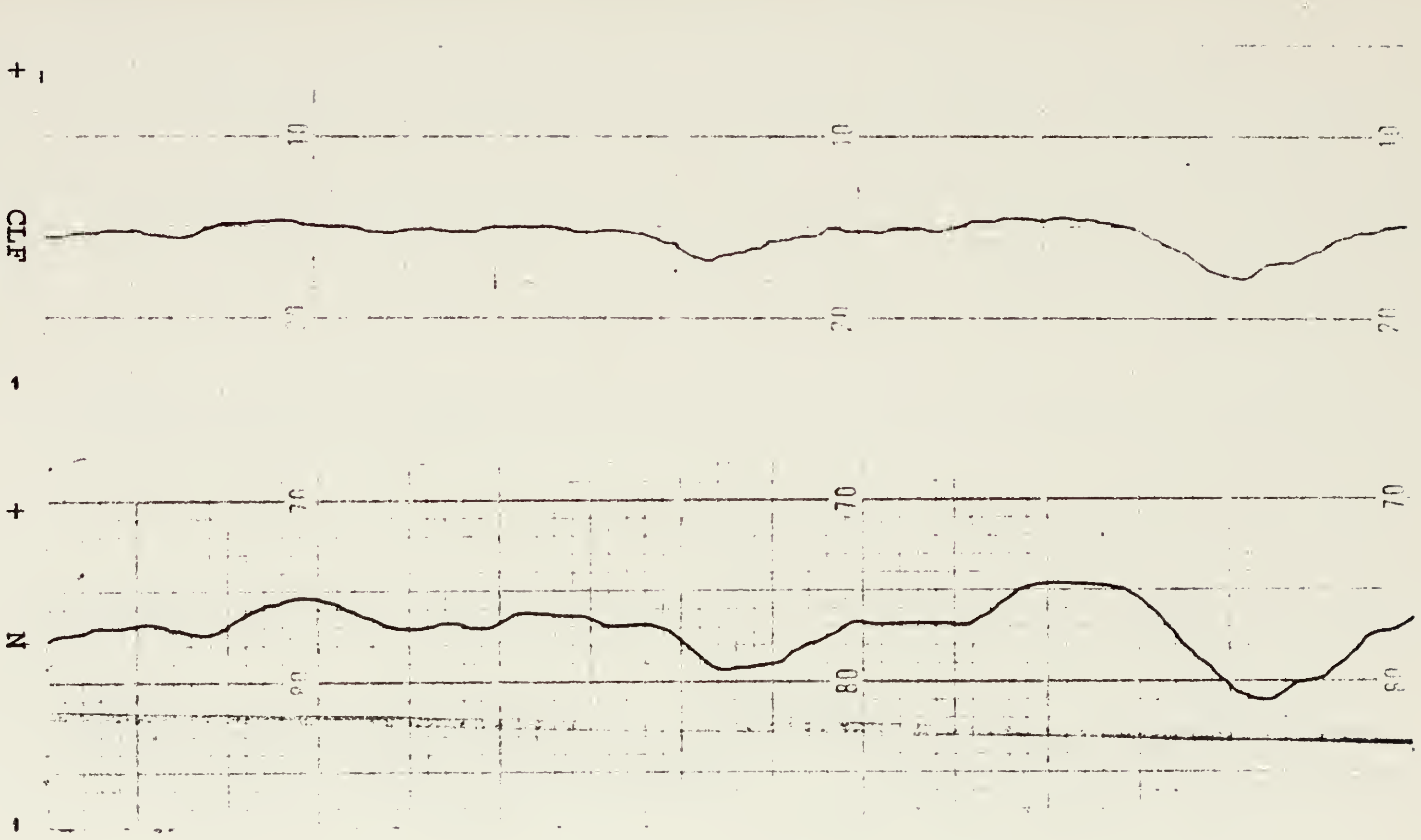


FIGURE 38. ANALOG RECORDING - CLOSURE FORCE VARIATIONS WITH RPM (16000 RPM)

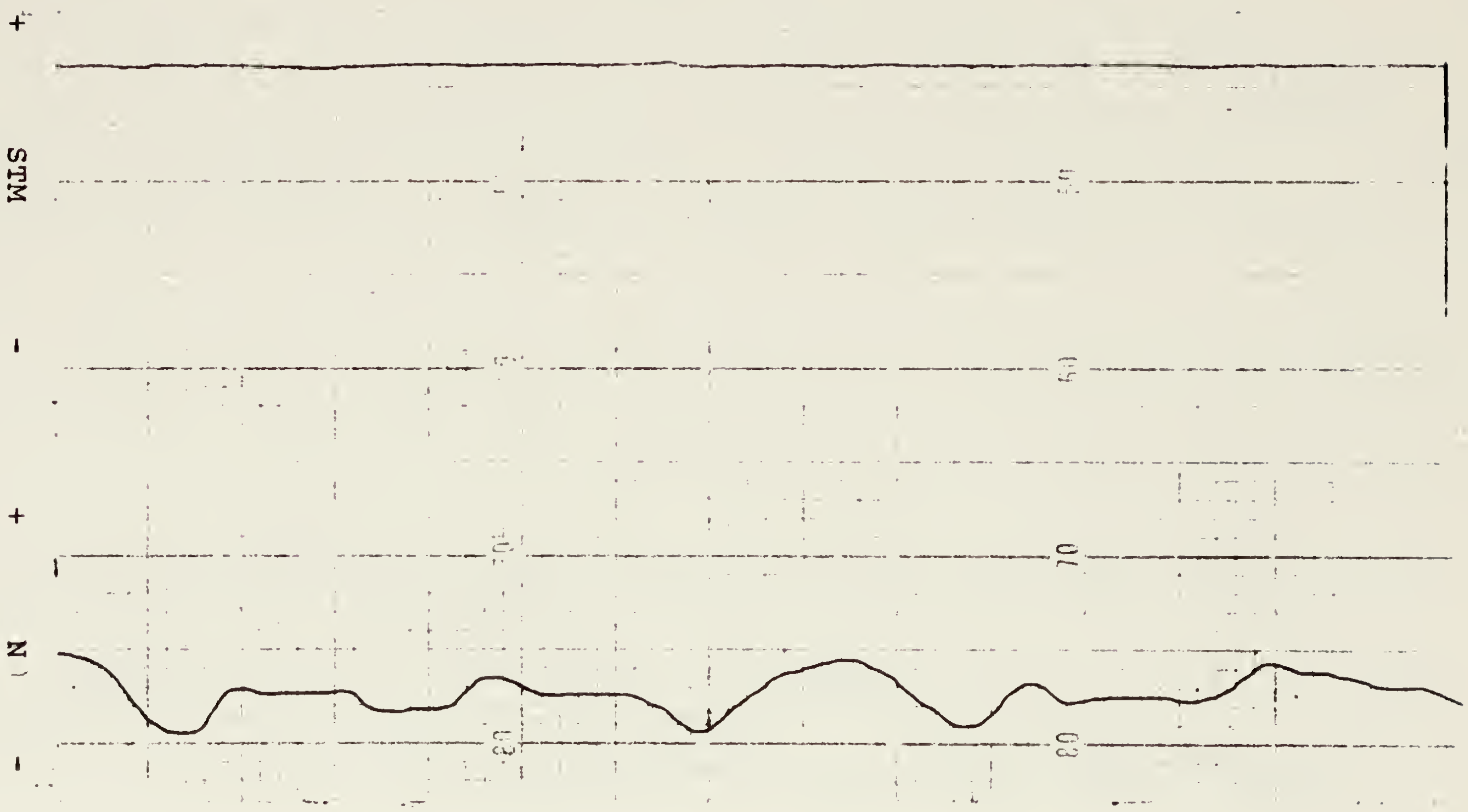


FIGURE 39. ANALOG RECORDING - STM VARIATIONS WITH RPM (16000 RPM)

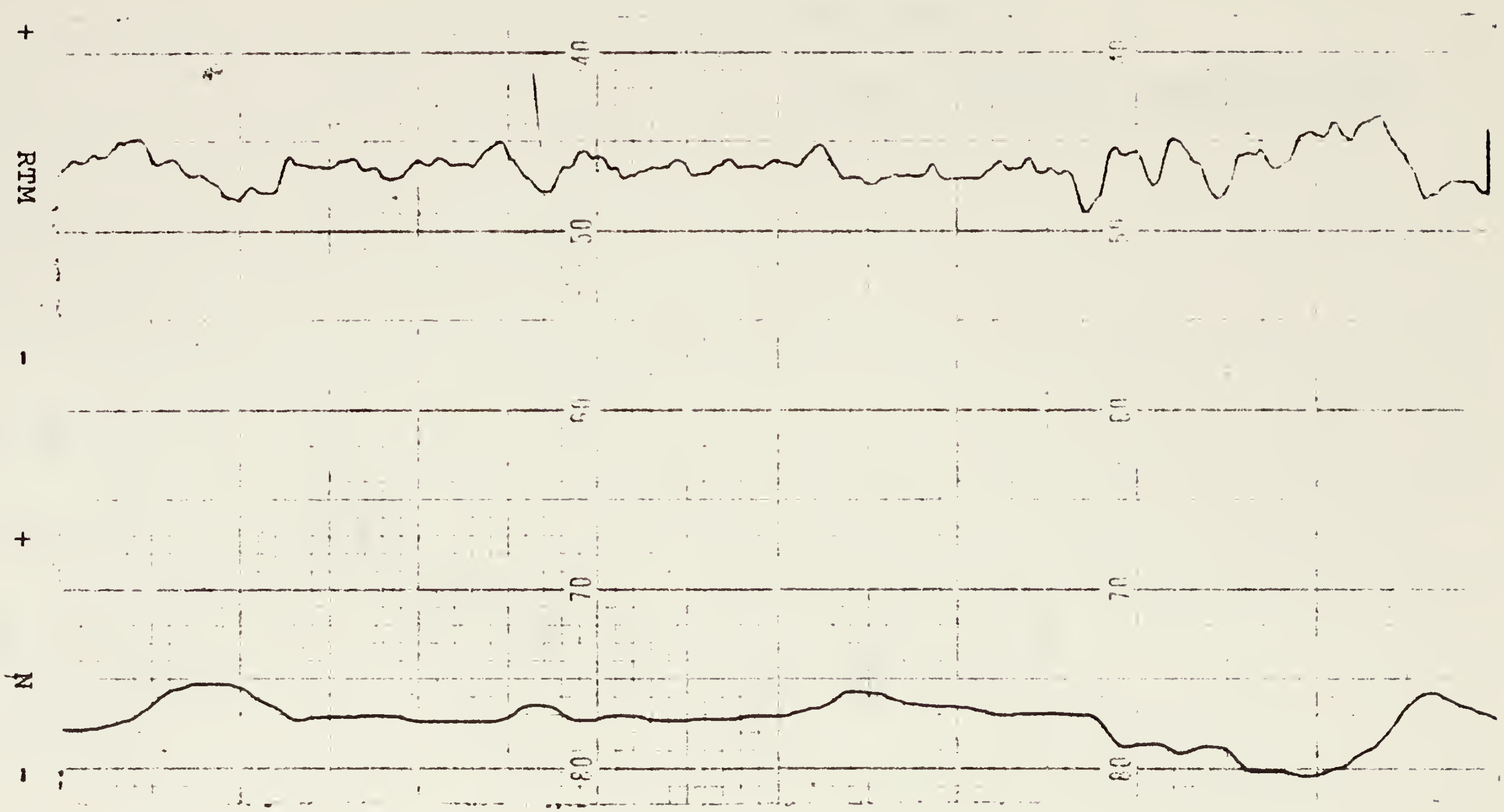


FIGURE 40. ANALOG RECORDING - RTM VARIATIONS WITH RPM (16000 RPM)

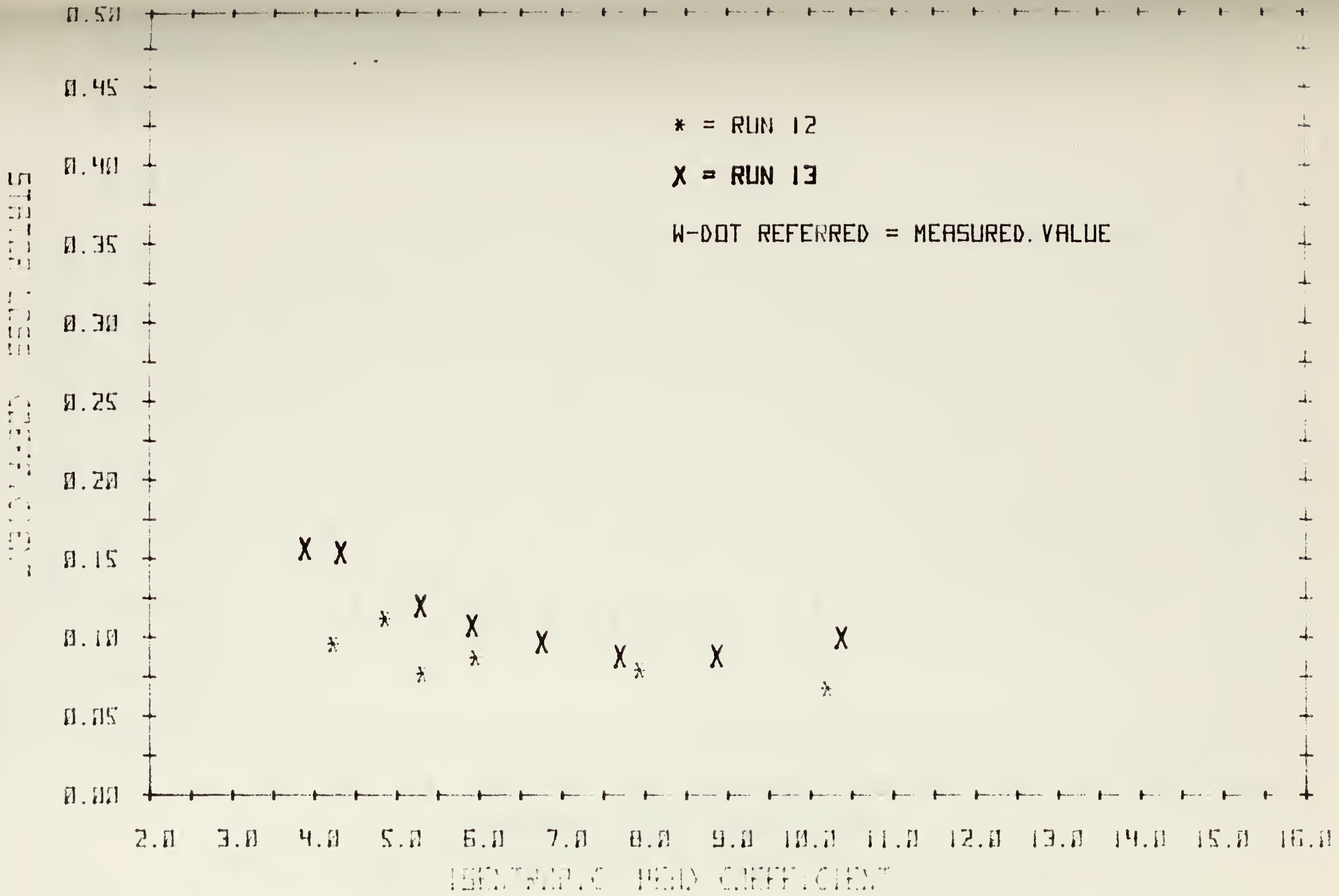


FIGURE 41. STATOR LOSS COEFFICIENT vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, $P_{t_o}$=60 in Hg, $T_{t_o}$=574° R, $\dot{W}_{ref}$ measured)

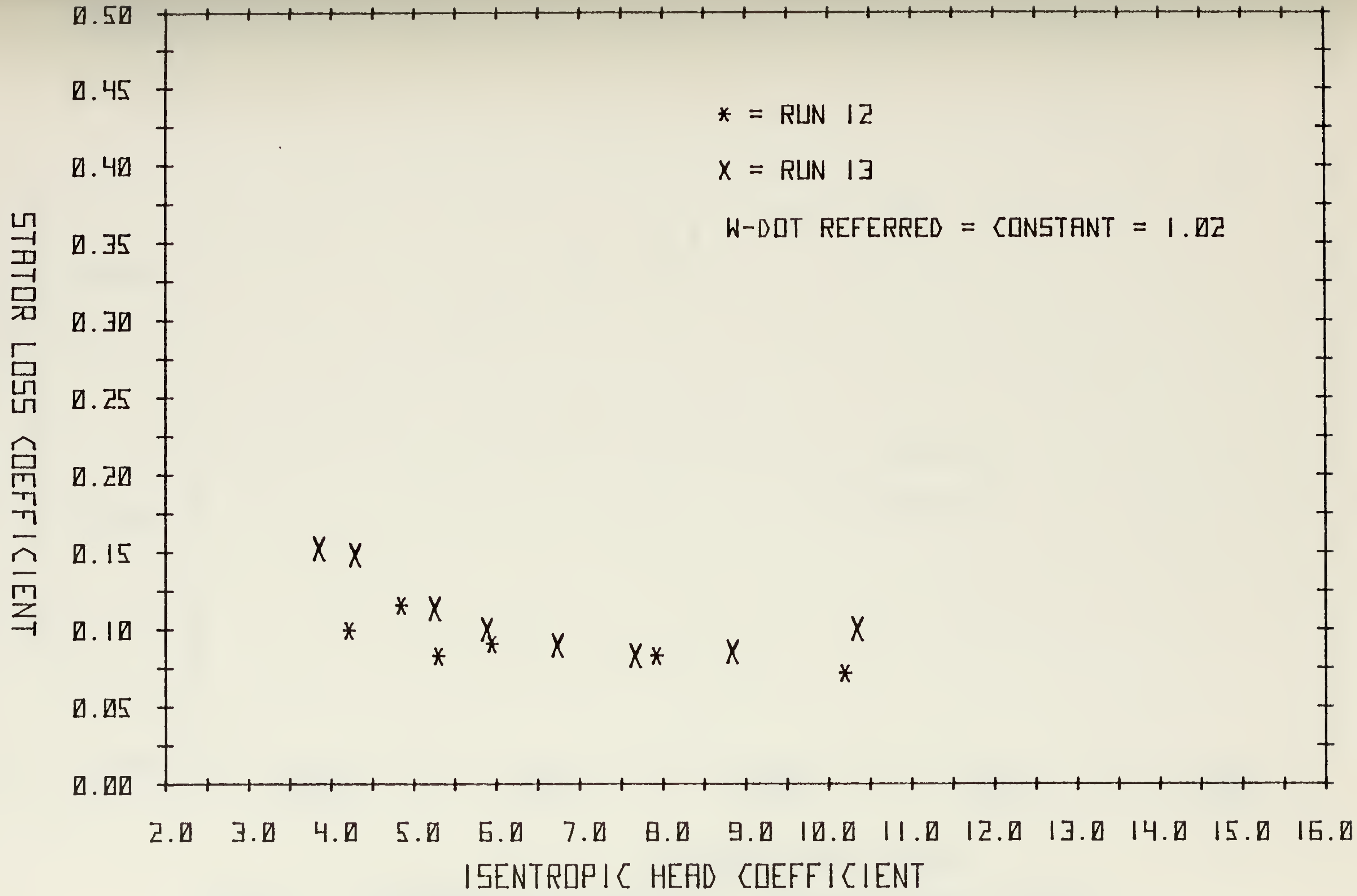


FIGURE 42. STATOR LOSS COEFFICIENT vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, $P_{t_o}$=60 in Hg, $T_{t_o}$=574° R, $\dot{W}_{ref}$=1.02=constant)

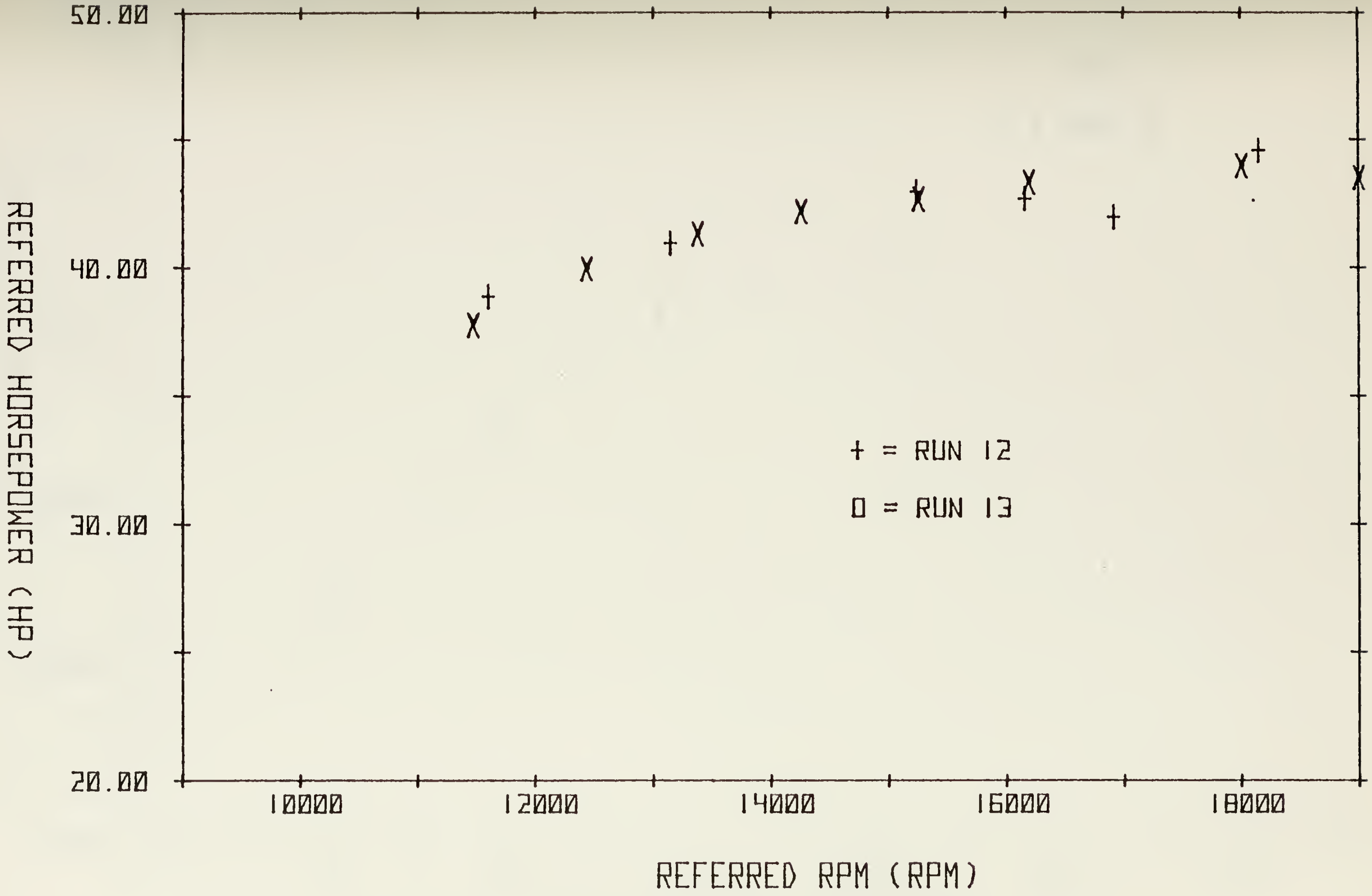


FIGURE 43. REFERRED HP vs. REFERRED N (PR=3.5, $P_{t_o}$ =60 in Hg, $T_{t_o}$=574° R)

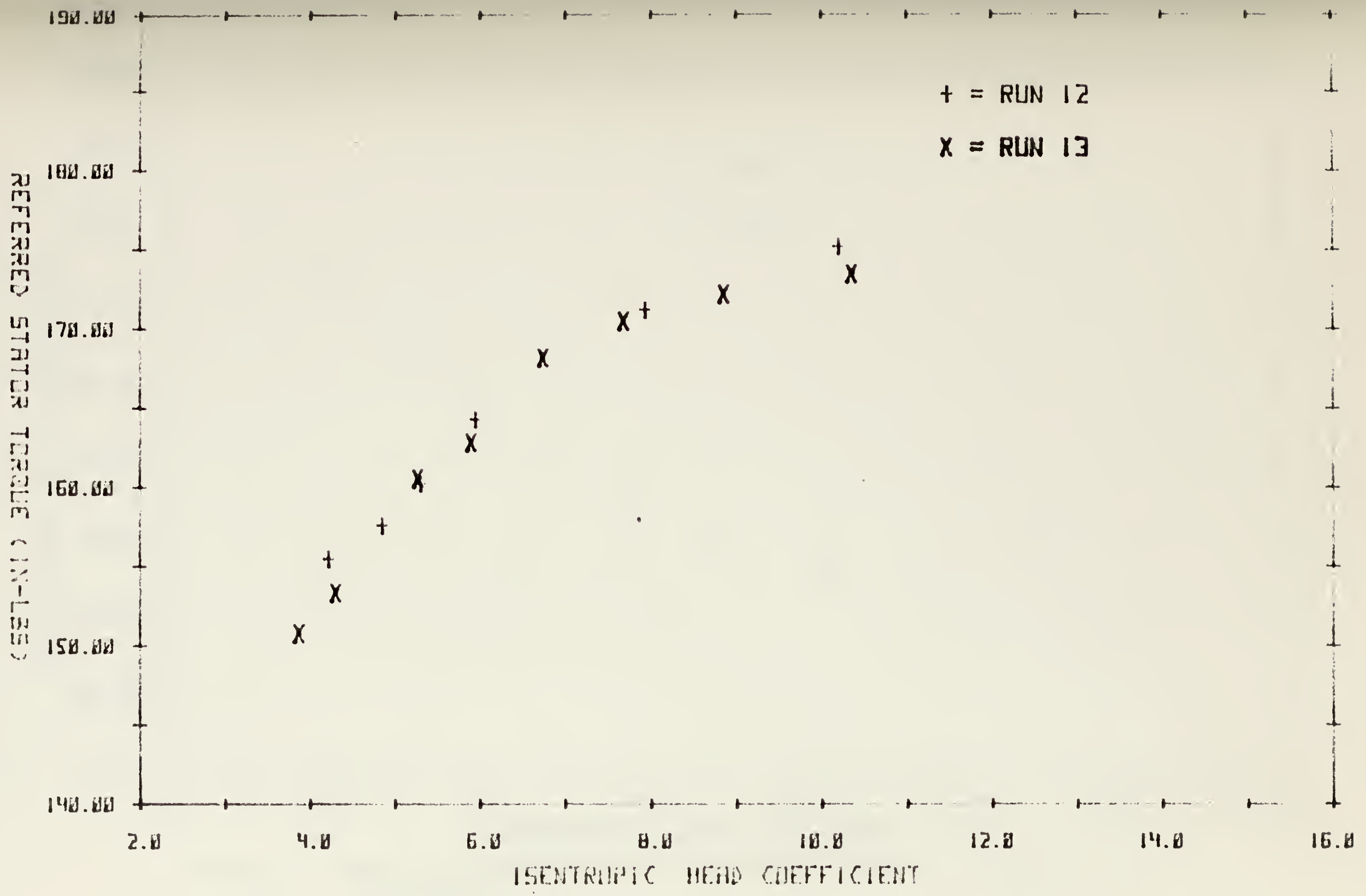


FIGURE 44. REFERRED STM vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, $P_{t_o}$=60 in Hg, $T_{t_o}$=574° R)

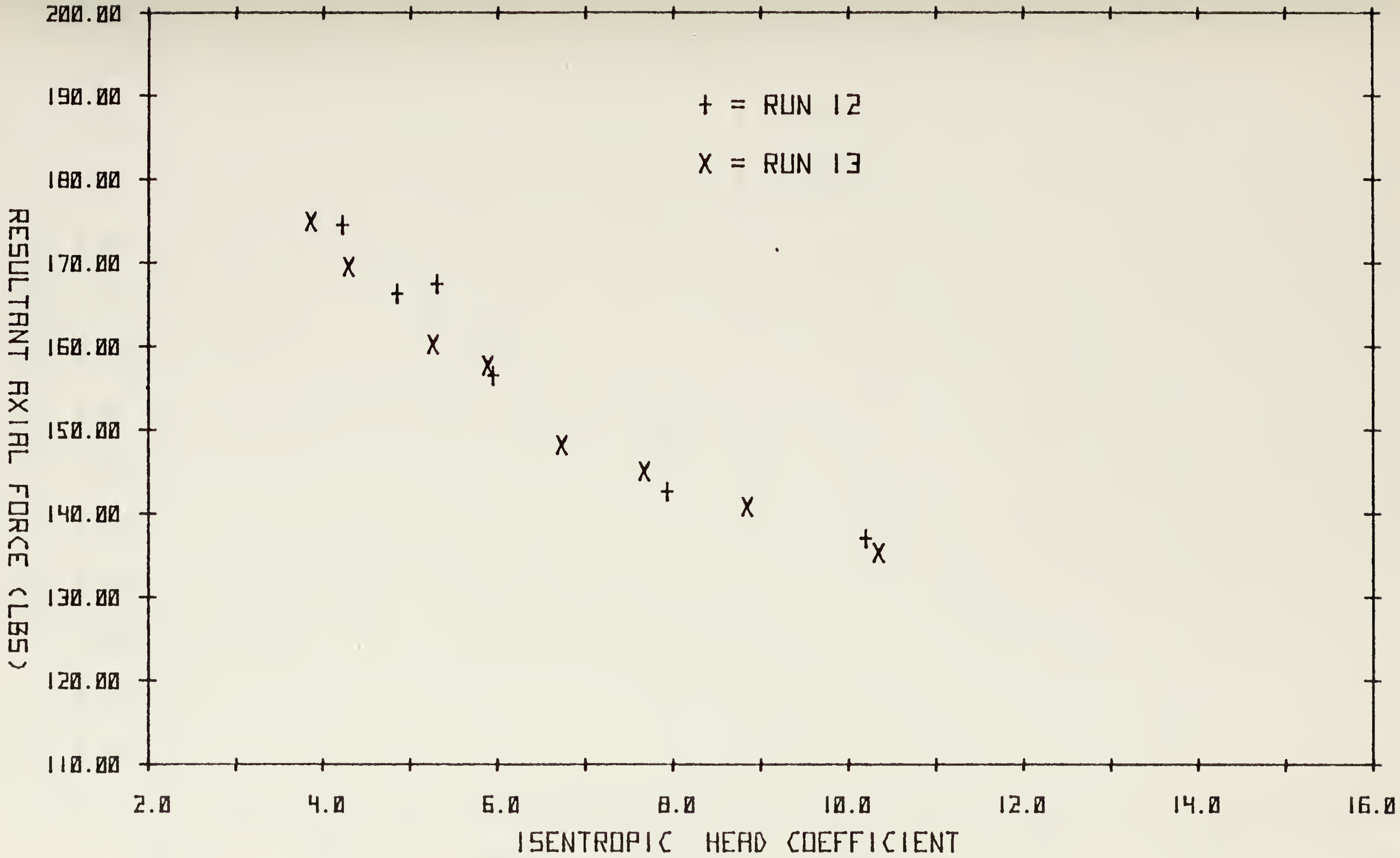


FIGURE 45. RAF vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, $P_{t_o}$=60 in Hg, $T_{t_o}$=574° R)

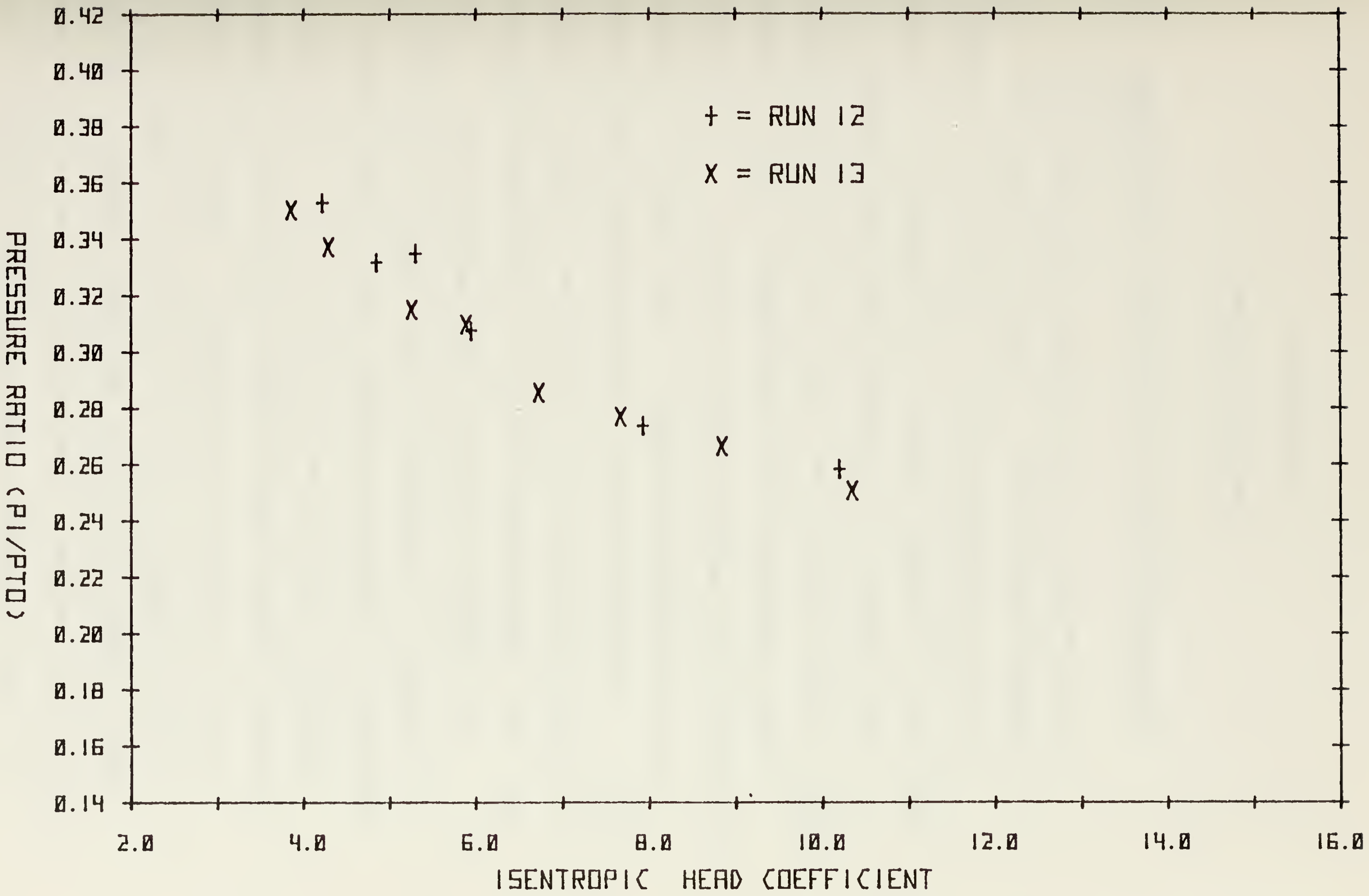


FIGURE 46. PRESSURE RATIO ($P_1/P_{t_0}$) vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, $P_{t_0}$=60 in Hg, $T_{t_0}$=574° R)

# APPENDIX A

# COMPUTER PROGRAMS

## A.1. ACQUISITION, REDUCTION, AND BATCH PROCESSING PROGRAMS

The acquisition program used to acquire data in Ref. 1 was entitled "SCATTR". The name was changed to "SCAMOD" and the changes to the program are listed in Table A-1. Listings of the current acquisition and reduction programs are given in Tables A-II through A-IX. Programs TTR7, TTR8, and TTR11 are currently used to batch process raw data, reduced data, and uncertainty data, respectively. Listings of these programs are contained in Tables A-X through A-XII. Reduction programs were also modified, and the changes are listed in Table A-I. A new program, "UNCERT", was added to the reduction sequence to calculate uncertainty in the loss coefficients, RAF, and $P_1/P_{t_o}$. The formulas used in program "UNCERT" were obtained from the uncertainty development in Appendix C. A current listing of the reduction sequence is presented in Figure A-1. It will be noticed that the smoothing procedure using TTR1 and TTR9 has been deleted from the reduction sequence. (Examination of Figures 31 and 32 clearly showed that addition of the "slingers" to the waterbrake assembly resulted in much less noise in the calculated values of $P_1$, yielding a smoother variation of $P_1/P_{t_o}$ than was seen in the data gathered in Ref. 1.)

Line 590 in TTR2, which allowed setting $W_{ref}$ = 1.02/lbm/sec = constant, was deleted since it had never been shown that the value should be constant at all test conditions. It will be noted that except for run 12, the $W_{ref}$ for runs 10-15 was fairly constant at around 1.025 lbm/sec +/-.005.

The storage and batch processing programs (TTR6 and TTR8) were modified to print out engineering data and other parameters. Some consideration should be given in the future to expanding the storage array to include engineering and other data. There is room for more data elements per record than is presently stored. For example, the Labyrinth flow rate, flow nozzle pressure, temperature, and pressure differential should be stored.

It was necessary to "scratch" the acquisition program at the end of each data point in order to reduce the data just taken. It is recommended that the feasibility of merging the acquisition program with the reduction sequence be studied and undertaken if possible. The only limiting factor is the number of variables left from the reduction sequence which can be used in the acquisition program. A current list of the variables used in the reduction sequence only is listed in Figure A-2.

Table A-XIII contains a list of all new variables added to the reduction programs. A list of all plotting routines located on the TTR disc and variables plotted are listed in Table A-XIV.

The programs used to acquire the RPM samples, "RPMSUR", and to compare calculated and measured temperature drops, "TERRY7", are listed in Tables A-XV and A-XVI respectively. A list of all programs used for acquiring, modifying, or reducing the data presented in this report is given in Table A-XVII.

On runs 13 and 15, variations in the recorded voltage values for a pressure port measurement indicated the pressure line had developed a leak. Accordingly, the reduction program was altered to compensate for this situation. Table A-XX lists the pertinent runs and points applicable, pressure port, and action taken in the reduction sequence. The voltage values are listed in Tables XX and XXII for Runs 13 and 15, respectively.

## A.2 FOURIER ANALYSIS PROGRAM

The program used for Fourier analyzing the RPM data was program "AUTOST" which is contained on tape and associated with the HP9845A computer system. The "DATA INPUT-TIME DOMAIN DATA" subprogram option was used and had to be modified as listed in Table A-XVIII. The data files containing the RPM data analyzed are recorded on the "TPL Library #1" tape in the NPS Turbomachinery Laboratory. The data file names are given in Table A-XVIII.

TABLE A-I

CHANGES IN THE ACQUISITION AND STORAGE PROGRAMS

| PROGRAM | LINE | ACTION | COMMENTS |
|---|---|---|---|
| SCAMOD (see note 1) | 100 | Added array E(2) | Averages point, 24 pressure |
| | 110 | added | Enters run #, day, month, year |
| | 160 | added | Takes multiple points without restarting program |
| | 180 | added | Loops program for multiple points |
| | 190 | added | assigns point number for data run |
| | 210/240 | added | Assigns point number when auto-storage not selected |
| | 350 and 1710-2280 (see note 2) | | Records 46 pressures on scanivalve system |
| | 860-990 | delete temperature averaging | extraneous |
| | 870-1690 | Recorded channel numbers changed (see Appendix B) | Changed channel setup |

TABLE A-1 (Cont'd)

| | | | |
|---|---|---|---|
| | 1050 and 2290-2960 | Port 24 averaged | Averaging sequence |
| TTRIB | 30 | added N(20) | "UNCERT" program storage array |
| | 40-50 | added counter "D" | Record # for storage of "UNCERT" data |
| | 443 | modified | channel number assignments |
| | 451 | modified | channel number assignments |
| | 632-634 | added | turbine outlet temperature |
| | 752-758 | added | pressure conversion to in. Hg |
| | 770-1080 | modified | scaling factors assignment |
| | 1100-1120 | modified | scaling factors assignment |
| | 1060 | changed | more stable port |
| | 1090,1150, 1160,1180, 1190 | modified | channel reassignment |
| | 1110 | changed | averaged channel used |
| TTR2 | 590 | deleted | eliminates constant $\dot{W}_{ref}$ |
| | 1127 | added | facilitates multiple single point reduction without smoothing |
| TTR3 | 580 | modified | chains to "UNCERT" for uncertainty calculations |
| UNCERT | All | added | calculates uncertainties |

TABLE A-1 (Cont'd)

| | | | |
|---|---|---|---|
| TTR5 | 60 | modified | channels reassignment |
| | 85 | added | prints $T_{t_o}$ |
| | 92,96 | added | prints calculated $\dot{W}$, $\dot{W}_{ref}$ |
| | 105 | added | turbine stator nozzle Reynolds Number printout |
| | 534-538 | added | $P_{T1P}/P_{t_o}$, $P_1/P_{t_o}$,<br>and $P_{HUB}/P_{t_o}$ printout |
| TTR6 | 470-510 | modified | different channels used |
| | 520-562 | added | stores 19 other data parameters (see note 3) |
| | 690-692 | added | chains to TTRIB for multiple point reduction with no smoothing |
| TTR7 | 270-330,<br>480-780 | modified | channels reassigned |
| | 348 | added | program loop more efficient |
| | 410 | added | "Table" format |
| TTR8 | Completely renumbered and reformatted to conform with 19 additional parameters stored in TTR6. | | |
| TTR11 | All | added | Batch processes the "UNCERT" data |

TABLE A-1 (Cont'd)

Note 1: Due to the extensive nature of the modifications to "SCATTR" (see Ref. 1), the program was changed to "SCAMOD" and renumbered. Major additions to the program are listed in the table.

Note 2: These lines replaced lines 110-210 of "SCATTR" program (see Ref. 1) due to replacement of the paper tape system with on-line data acquisition.

Note 3: The nineteen additional stored items, beginning with line 520, are:

| Line | Program Variable | Parameter |
|---|---|---|
| 520 | Z9 | $\dot{W}$ |
| 525 | V9 | $\dot{W}_{ref}$ |
| 530 | Q8 | Re No. (Stator) |
| 532 | H1 | Horsepower |
| 534 | M5 | Rotor Torque |
| 536 | M6 | Stator Torque |
| 538 | F4 | Stator Axial Force |
| 540 | F5 | Closure Plate Force |
| 542 | R2 | Resultant Force on stator |
| 544 | Q1 | $P_{t_o}$ |
| 546 | T2 | $T_{t_o}$ |
| 548 | Q3 | Hood Pressure |

TABLE A-1 (Cont'd)

|  |  |  |
|---|---|---|
| 550 | Q4 | Static pressure at stator tap "Tip #3" |
| 552 | S0 | Stator Exit Pressure |
| 554 | R8 | Static pressure at stator tap "HUB #3" |
| 556 | Q4/Q1 | $P_{TIP}/P_{t_o}$ |
| 558 | P2 | $P_1/P_{t_o}$ |
| 560 | R8/Q1 | $P_{HUB}/P_{t_o}$ |
| 562 | T2-T1 | Temperature difference across the stage |

## TABLE A-II

## PROGRAM "SCAMOD"

```
10 REM      PROGRAM NAME: SCAMOD
20 REM      PROGRAM DISC: TURBINE TEST RIG PL-002
30 PRINT "CHECK APPROPRIATE FILENAME, LINES 500,610, AND VALUE OF K, LINE"
40 PRINT "1030 TO ENSURE YOU HAVE THE NUMBER OF SCANS DESIRED, CONTINUE 100"
50 PRINT
60 PRINT
70 PRINT
80 PRINT
90 STOP
100 DIM CS[27],AS[48],DS[30,40],B$[20],E[2]
110 DISP "ENTER RUN #,DATE (MONTH, DAY, YEAR)";
120 INPUT R1,M0,D0,Y1
130 DISP "AUTO STORAGE? YES=1, NO=0";
140 INPUT Z
150 IF Z=0 THEN 210
160 DISP "ENTER FIRST RECORD # THIS RUN,TOTAL # OF POINTS DESIRED THIS RUN";
170 INPUT E1,E2
180 FOR Q=1 TO E2
190 P1=Q
200 GOTO 250
210 P1=0
220 DISP "ENTER NEXT RECORD # ON DATA FILE";
230 INPUT E1
240 P1=P1+1
250 MAT A=ZER
260 MAT C=ZER
270 MAT D=ZER
280 PRINT
290 PRINT
300 PRINT
310 PRINT
320 WRITE (15,330)R1,P1,M0,D0,Y1,"     TURBINE C"
330 FORMAT "RUN",F4.0,1X,"PT.",F4.0,2X,"DATE",F4.0,1X,F4.0,1X,F4.0,F4.0
340 GOSUB 760
350 GOSUB 1710
```

TABLE A-II (Cont'd)

```
360 REM************DATA CORRECTIONS*********************************************
370 DISP "CORRECTIONS TO DATA?-YES=1,NO=0";
380 INPUT G1
390 IF G1=0 THEN 490
400 DISP "PRESS PRT ALL KEY FOR RECORD.";
410 WAIT 7000
420 DISP "ENTER CORRECTION AS MATRIX ELEMENT";
430 WAIT 7000
440 DISP "ENTER CORRECT VALUE=?; EXEC.,CONT.,EXEC.";
450 STOP
460 DISP "ANY MORE CORRECTIONS? YES=1,NO=0";
470 INPUT G1
480 IF G1=1 THEN 440
490 REM**********STORE RAW DATA IN FILES RAWDAT*********************************
500 FILES RAWDAT
510 DISP "STORE DATA? ENTER YES=1,NO=0";
520 INPUT G1
530 IF G1=0 THEN 700
540 C[10]=R1
550 C[11]=P1
560 C[12]=M0
570 C[13]=D0
580 C[14]=Y1
590 MAT PRINT # 1,E1;C,A
600 PRINT
610 PRINT "THE RAW DAT IS STORED IN RAWDAT RECORD # "E1
620 PRINT
630 PRINT
640 IF Z=0 THEN 220
650 E1=E1+1
660 DISP "PRESS CONT WHEN READY FOR NEXT PT";
670 STOP
680 NEXT Q
690 GOTO 740
700 PRINT "THIS DATA WAS NOT STORED"
```

## TABLE A-II (Cont'd)

```
710 DISP "DO YOU WISH TO CONTINUE; YES=1,NO=0";
720 INPUT G1
730 IF G1=1 THEN 100
740 STOP
750 END
760 REM**********FUSCAN**********W.J.KANE**********12/1/78
770 REM
780 REM     DISCRIPTION: THIS SUBROUTINE IS DESIGNED TO RECORD THE NINE
790 REM                  NON-PRESSURE CHANNELS CONNECTED WITH THE TURBINE
800 REM                  TEST RIG DATA GATHERING SYSTEM
810 CMD "?D"
820 FORMAT 4B
830 FORMAT 3B
840 FORMAT F3.0
850 OUTPUT (13,820)256,20,768,512;
860 REM*****BEGIN SCAN****************************************
870 B$="F1R7M3T3"
880 CMD "?D#",B$
890 B$="PF4G5S0"
900 CMD "?D%",B$
910 FOR I=0 TO 6
920 CMD "?D("
930 OUTPUT (13,840)I
940 CMD "?D#"
950 OUTPUT (13,830)256,8,512
960 CMD "?C$"
970 ENTER (13,*)A0
980 C[I+1]=A0
990 NEXT I
1000 CMD "?D(","C"
1010 REM*****THE VALUE OF K ENTERED NEXT REPRESENTS THE NUMBER OF SCANS
1020 REM*****USED IN AVERAGING THE NON-PRESSURE VALUES
1030 K=36
1040 FOR J=1 TO K
1050 GOSUB 2290
```

TABLE A-II (Cont'd)

```
1060 D[J,17]=E[1]
1070 WRITE (13,820)256,20,768,512;
1080 B$="F1R7M3T3"
1090 CMD "?D#",B$
1100 B$="PF4G5S0"
1110 CMD "?D%",B$
1120 OUTPUT (13,820)256,8,768,512;
1130 FOR I=16 TO 27
1140 IF I=17 THEN 1290
1150 IF I=22 THEN 1300
1160 CMD "?D!"
1170 OUTPUT (13,840)I
1180 IF I=16 THEN 1220
1190 CMD "?D#"
1200 OUTPUT (13,820)256,8,768,512;
1210 GOTO 1250
1220 CMD "?D%","T"
1230 CMD "?E$"
1240 GOTO 1260
1250 CMD "?C$"
1260 ENTER (13,*)A0
1270 D[J,I]=A0
1280 GOTO 1300
1290 I=I+2
1300 NEXT I
1310 CMD "?D!","C"
1320 NEXT J
1330 CMD "?D!","C"
1340 PRINT
1350 PRINT "THE FOLLOWING ARE THE NON-S/V CHANNEL READINGS"
1360 PRINT
1370 PRINT
1380 PRINT N;"SCANS COMPLETED"
1390 PRINT
1400 FOR J=16 TO 27
```

TABLE A-II (Cont'd)

```
1410 IF J=18 THEN 1510
1420 IF J=22 THEN 1510
1430 S1=0
1440 FOR I=1 TO K
1450 S1=S1+D[I,J]
1460 NEXT I
1470 IF J#16 THEN 1500
1480 C[16]=((S1/K)*2)
1490 GOTO 1510
1500 C[J]=S1/K
1510 NEXT J
1520 WRITE (15,1540)C[16]
1530 FORMAT "CHANNEL",F3.0,"=",F10.6
1540 FORMAT "RPM =",F10.0,/
1550 FOR J=0 TO 27
1560 IF J<7 THEN 1600
1570 IF J>19 THEN 1620
1580 J=J+12
1590 GOTO 1640
1600 WRITE (15,1530)J,C[J+1]
1610 GOTO 1640
1620 IF J=22 THEN 1640
1630 WRITE (15,1530)J,C[J]
1640 NEXT J
1650 WRITE (15,1660)
1660 FORMAT /,"S/V=1",/,/,"PORT",4X,"PRESSURE"
1670 WRITE (15,1680)C[17]
1680 FORMAT 1X,"24",1X,F12.6
1690 RETURN
1700 END
1710 REM**********HAMMOD**********T.P.EARGLE*****7/17/79************************
1720 REM      DATE:    NOV 79
1730 REM
1740 FORMAT E
1750 FORMAT 8B
```

TABLE A-II (Cont'd)

```
1760 FORMAT 4B
1770 FORMAT F3.0
1780 WRITE (13,1760)256,20,768,512;
1790 CMD "?D#","F1R7M3A1H1T3"
1800 V=1
1810 CMD "?D'"
1820 WRITE (13,1740)V;
1830 WRITE (15,1840)V
1840 FORMAT "SCANIVALVE #",F3.0,/,/," PORT",8X,"VOLTAGE",8X,"PORT",8X,"VOLTAGE"
1850 FOR B=1 TO 48
1860 GOSUB 2020
1870 CMD "?D!"
1880 WRITE (13,1770)V+9
1890 CMD "?D#","T3"
1900 CMD "?C$"
1910 ENTER (13,*)V0
1920 A[B]=V0
1930 CMD "?D!","C"
1940 NEXT B
1950 FOR B=1 TO 48 STEP 2
1960 WRITE (15,1970)B,A[B],B+1,A[B+1]
1970 FORMAT 1X,F3.0,4X,F12.6,9X,F3.0,4X,F12.6
1980 NEXT B
1990 RETURN
2000 STOP
2010 REM  SUBROUTINE "POSIT"
2020 GOSUB 2200
2030 D=B-P
2040 CMD "?D!"
2050 IF D<0 THEN 2080
2060 IF D>0 THEN 2130
2070 RETURN
2080 REM    HOME S/V
2090 WRITE (13,1770)V+4
2100 WRITE (13,*)"C"
```

TABLE A-II (Cont'd)

```
2110 WAIT 4000
2120 GOTO 2020
2130 REM      ADVANCE S/V
2140 FOR I=1 TO D
2150 WRITE (13,1770)V-1
2160 WRITE (13,*)"C"
2170 WAIT 50
2180 NEXT I
2190 GOTO 2020
2200 REM      READ S/V ADDRESS
2210 CMD "?G$"
2220 P0=RBYTE13
2230 L=BIAND(P0,15)
2240 T=ROT(P0,4)
2250 M=BIAND(T,7)
2260 P=10*M+L
2270 WRITE (13,1750)256,95;
2280 RETURN
2290 REM      FILE NAME: "HAM2"
2300 REM      DISC LABEL: PL-006 (MCGUIRE)
2310 REM
2320 REM      DESCRIPTION:
2330 REM        THIS PROGRAM PERFORMS SEQUENTIAL SCANNING
2340 REM      OF SCANIVALVE 'V' BETWEEN PORT ADDRESSES SPECIFIED.
2350 REM
2360 REM      VARIABLES:
2370 REM        V  = DESIRED S/V
2380 REM        A1 = LOW PORT
2390 REM        A2 = HIGH PORT
2400 REM        P  = PRESENT S/V PORT
2410 REM        S  = STEP SIZE
2420 REM
2430 REM      AUTHOR: R.N. GEOPFARTH,LT USN
2442 REM      DATE:   FEB 79
2450 REM
```

## TABLE A-II (Cont'd)

```
2460 FORMAT B
2470 FORMAT 2B
2480 FORMAT 4B
2490 FORMAT F3.0
2500 WRITE (13,2480)256,20,768,512;
2510 CMD "?D#","F1R7M3A1H1T3"
2520 V=1
2530 T1=1
2540 S=1
2550 CMD "?D'"
2560 WRITE (13,2460)V;
2570 FOR A=24 TO 24
2580 GOSUB 2700
2590 CMD "?D!"
2600 WRITE (13,2490)V+9
2610 CMD "?D#","T3"
2620 CMD "?C$"
2630 ENTER (13,*)V0
2640 E[T1]=V0
2650 CMD "?D!","C"
2660 NEXT A
2670 RETURN
2680 STOP
2690 REM  SUBROUTINE "POSIT"
2700 GOSUB 2880
2710 D=A-P
2720 CMD "?D!"
2730 IF D<0 THEN 2760
2740 IF D>0 THEN 2810
2750 RETURN
2760 REM     HOME S/V
2770 WRITE (13,2490)V+4
2780 WRITE (13,*)"C"
2790 WAIT 4000
2800 GOTO 2700
```

## TABLE A-II (Cont'd)

```
2810 REM      ADVANCE S/V
2820 FOR I=1 TO D STEP S
2830 WRITE (13,2490)V-1
2840 WRITE (13,*)"C"
2850 WAIT 50
2860 NEXT I
2870 GOTO 2700
2880 REM      READ S/V ADDRESS
2890 CMD "?G$"
2900 P0=RBYTE13
2910 L=BIAND(P0,15)
2920 T=ROT(P0,4)
2930 M=BIAND(T,7)
2940 P=10*M+L
2950 WRITE (13,2470)256,95;
2960 RETURN
```

## TABLE A-III

## PROGRAM "TTR1B"

```
1 PRINT "PRIOR TO RUNNING THIS SEQUENCE ENSURE FOLLOWING:"
2 PRINT "ENSURE THAT TTR1 AND TTR1B HAVE THE PROPER FILE NAME IN LINE 441"
3 PRINT "THAT TTR2 LINE 590 HAS PROPER FACTOR IN IT;"
4 PRINT "                 1.01 FOR UNHOODED"
5 PRINT "                  1.02 FOR HOODED                    "
6 PRINT "IF IT IS DESIRED TO RUN A SINGLE POINT, WITHOUT SMOOTHING,TO CHECK"
7 PRINT "DATA,INSERT TTR2-1127 'GO TO 1200'. OTHERWISE,REMOVE THIS LINE."
8 PRINT "IF IT IS DESIRED TO STORE REDUCED DATA,SET TTR6-580 TO".
9 PRINT "'G1=1',OTHERWISE SET G1=0."
10 PRINT "ENSURE THAT TTR6-610,630 HAVE THE PROPER FILE NAME FOR REDUCED DATA"
11 PRINT "ENSURE TTR7-220 HAS THE PROPER FILE NAME FOR RAW DATA"
12 PRINT "ENSURE TTR8-220 HAS THE PROPER FILENAME FOR REDUCED DATA."
17 PRINT "TEAR  THIS OFF AND CONTINUE 20"
18 STOP
19 REM----------*****TTR1B*****-------------------------------------------
20 REM----------DATA REDUCTION FOR TURBINE C/MASS MEMORY-----------------------
21 DISP "LOWEST/HIGHEST RECORD # THIS RUN";
22 INPUT A7,A2
24 A7=A7-1
25 A5=A7
26 F8=A7
27 A6=0
30 DIM C[66],AS[48],QS[20],DS[75],B[10],SS[50],ZS[75],NS[20]
31 DISP "PRINT-OUT RESULTS YES=1,NO=0";
32 INPUT Q5
40 DISP "INPUT NEXT RECORD # FOR DATA2, UNCERT STORAGE FILE";
50 INPUT D
70 MAT A=ZER
80 MAT C=ZER
437 A7=A7+1
438 IF (A7=A2+1) THEN 1401
441 FILES RAWDAT
442 MAT READ # 1,A7;Z
443 FOR I=1 TO 27
```

TABLE A-III (Cont'd)

```
444 C[I]=Z[I]
445 NEXT I
446 FOR I=28 TO 75
447 J=I-27
448 A[J]=Z[I]
449 NEXT I
451 N=C[16]
610 P0=29.92
620 T0=518.7
630 REM----------TEMPERATURES-----------------------------------------------
632 S=1E+03*C[6]
634 T1=FNT(S)+460
640 S=1E+03*C[5]
650 T2=FNT(S)+460
670 S=1E+03*C[2]
680 T5=FNT(S)+460
700 S=1E+03*C[7]
710 T6=FNT(S)+460
750 REM----------PRESSURES ASSIGNMENT---------------------------------------
752 FOR I=3 TO 48
754 A[I]=(A[I]-A[1])*100/13.596+C[25]*10
756 NEXT I
758 C[17]=(C[17]-A[1])*100/13.596+C[25]*10
760 R9=14.696/P0
770 N8=A[29]*1000
780 N9=A[30]*1000
790 O1=A[31]*1000
800 S3=A[32]*1000
810 S4=A[33]*1000
820 S5=A[34]*1000
830 S6=A[35]*1000
840 S7=A[36]*1000
850 S8=A[37]*1000
```

TABLE A-III (Cont'd)

```
860  S9=A[ 38 ]*1000
870  N0=A[ 39 ]*1000
880  N1=A[ 40 ]*1000
890  N2=A[ 41 ]*1000
900  N3=A[ 42 ]*1000
910  N4=A[ 43 ]*1000
920  N5=A[ 44 ]*1000
930  N6=A[ 45 ]*1000
940  N7=A[ 46 ]*1000
950  D0=A[ 17 ]*1000
960  D1=A[ 12 ]*1000
970  D2=A[ 18 ]*1000
980  D3=A[ 13 ]*1000
990  D4=A[ 19 ]*1000
1000  D5=A[ 22 ]*1000
1010  D6=A[ 14 ]*1000
1020  D7=A[ 15 ]*1000
1030  D8=A[ 20 ]*1000
1040  D9=A[ 23 ]*1000
1050  E3=A[ 16 ]*1000
1060  Q0=A[ 27 ]*1000
1070  Q3=A[ 11 ]*1000
1080  Q1=1000*((A[ 6 ]+A[ 7 ]+A[ 8 ]+A[ 9 ]+A[ 10 ])/5)
1090  H0=C[ 27 ]*1E+04
1100  P7=A[ 3 ]*1000
1110  Q4=C[ 17 ]*1000
1120  R8=A[ 21 ]*1000
1130  J2=C[ 25 ]*10000
1140  REM----------FORCE ASSIGNMENT--------------------------------------------
1150  F4=C[ 20 ]*1E+05
1160  F5=C[ 21 ]*1E+04
1170  REM----------MOMENT ASSIGNMENT-------------------------------------------
1180  M5=C[ 23 ]*1E+05
1190  M6=C[ 24 ]*1E+05
1200  REM-----------STORE RAW DATA IN FILES RAWDAT------------------------------
```

TABLE A-III (Cont'd)

```
1320 CHAIN "TTR2"
1330 END
1340 REM-----------TEMPERATURE SUBROUTINE-----------------------------------------
1350 DEF FNT(S)
1360 S1=32.144+35.77*S-0.4518*S↑2
1370 S2=33.252+34.86*S-0.1855*S↑2
1380 IF S1<100 THEN 1400
1390 S1=S2
1400 RETURN S1
1401 STOP
```

## TABLE A-IV

## PROGRAM "TTR2"

```
10 REM-----*****TTR 2*****------------------------------------------------
20 REM----------PROGRAM TO CALCULATE MASS FLOW RATE-----------------------
30 C1=0.2402
40 J0=778.12
50 C0=53.35
60 C3=32.174
70 G0=0.2867332382
80 C2=3.25
90 C4=7.975
100 C6=0.1148235718
110 C5=C2/C4
120 C7=1
130 C8=1+0.00193*(T5-528)/100
140 C9=1-0.05246*((0.41+0.35*C5↑4)*(H0/P7))
150 K0=(1.153E-05*0.06333*T5↑0.5)/((198.72/T5)+1)
160 P1=Q3/Q0
170 K1=0.8
180 K2=SQR((1-P1↑2)/(10-LOG(P1)))
190 K3=K1*K2*2*PI*6.4*0.0075*Q0
200 W1=K3/(2.036*SQR(53.34*T6/32.174))
210 R1=(6*W1)/(PI*6.4*K0)
220 K=0.601373889233+0.000436695141492*R1
230 K=K-0.000000245308607545*R1↑2
240 K=K+(6.56722336557E-11)*R1↑3
250 K=K-(6.08657310341E-15)*R1↑4
260 IF ABS(K-K1)<0.0001 THEN 361
270 K5=4.36695141492E-04-2*R1*2.45308607545E-07
280 K5=K5+3*R1↑2*6.56722336557E-11
290 K5=K5-4*R1↑3*6.08657310341E-15
300 W2=W1*(1+(K-K1)/(K1-K5*R1))
310 K6=2*PI*6.4*0.0075
320 K7=1/K2
330 K7=(K7*2.036*W2*SQR(53.34*T6/32.174))/(K6*Q0)
340 K1=K7
350 W1=W2
```

TABLE A-IV (Cont'd)

```
360 GOTO 210
361 IF (F8 <= A2) THEN 410
362 IF (Q5=0) THEN 410
370 PRINT
380 PRINT "W-DOT LAB  =";W1
390 PRINT "RE*E-03 LAB=";R1
400 PRINT "K.E. FACTOR=";K
410 W3=C6*C2↑2*C7*C8*C9*(P7*H0/T5)↑0.5
420 R=(C5*48*W3)/(PI*C4*K0*1E+06)
430 K8=1.0272-0.1598*R+0.3805*R↑2
440 W=C6*C2↑2*K8*C8*C9*(P7*H0/T5)↑0.5
450 IF ABS(W-W3)<0.00001 THEN 471
460 W3=W-0.8*(W-W3)
470 GOTO 420
471 W0=W-W1
473 Z9=W0
480 IF (F8 <= A2) THEN 551
481 IF (Q5=0) THEN 540
490 PRINT "KN         =";K8
500 PRINT "W-DOT NOZ  =";W
510 PRINT "RE*E-06 NOZ=";R
520 PRINT "W-DOT      =";W0
530 PRINT
540 REM----------THE NEXT TEN STEPS CALCULATE NEW FLOW RATE BASED ON A GIVEN----
550 REM----------BLOCKAGE FACTOR----------------------------------------
551 Q2=Q1/P0
552 T3=(T2/T0)↑0.5
560 V9=Z9*T3/Q2
591 IF (F8 <= A2) THEN 610
592 IF (Q5=0) THEN 610
600 PRINT "NEW FLOW RATE=";W0
610 U9=W0*2.036*SQR(C0/C3*T2)/(2.968*Q1)
620 V8=U9/0.68473
631 IF (F8 <= A2) THEN 670
632 IF (Q5=0) THEN 660
```

TABLE A-IV (Cont'd)

```
630 PRINT "STATOR FLOW FUNCTION =";U9
640 PRINT "STATOR BLOCKAGE FACTOR=";V8
650 PRINT "    "
660 REM----------THIS PART OF THE PROGRAM EVALUATES CONTROL VOLUME A--------
670 W4=W0/C3
680 P9=(S9+Q3)/2
710 R0=N/T3
720 M0=M5/Q2
730 W5=W0*T3/Q2
740 A1=47.66118069
750 A0=82.51589456
760 REM----------THE NEXT STEPS INTEGRATE EXIT SURFACE PRESSURES OVER THE AREA--
770 F0=N8*0.250005899+N9*0.501457199+O1*0.503384401
780 F1=S3*0.5053116039+S4*0.507238805+S5*0.509166007
790 A8=S6*0.511093209+S7*0.513020411+S8*0.514947613
800 A9=S9*0.516874815+N0*0.518802017+N1*0.520729219
810 B5=N2*0.522656421+N3*0.524583623+N4*0.526510825
820 B6=N5*0.711139415+((N6+N7)/2)*9.619983952
830 B7=1.896906211*Q4
840 F0=F0+F1+A8+A9+B5+B6+B7
850 F2=R8*A1
860 F3=A0*Q3
870 R2=F4+F5+0.491159*(F3-F2-F0)
880 V0=M6/(W4*4.18375)
881 IF (F8 <= A2) THEN 900
882 IF (Q5=0) THEN 900
890 PRINT "V0=";V0
900 V1=109.62*SQR(T2)
901 IF (F8 <= A2) THEN 920
902 IF (Q5=0) THEN 920
910 PRINT "V1=";V1
920 X0=V0/V1
921 IF (F8 <= A2) THEN 931
922 IF (Q5=0) THEN 931
930 PRINT "X0=";X0
```

TABLE A-IV (Cont'd)

```
931 U1=((8.945+7.79)/48)*N*PI/30
932 U2=((9.348+7.6525)/48)*N*PI/30
933 U3=U1/V1
934 U4=U2/V1
935 P4=P9/Q1
936 K4=(1-P4↑G0)/U4↑2
940 DEG
1060 X7=1
1061 V7=W4*V1*2.036/(Q1*15.1809022)
1070 X8=1.402*(2*X7-1)+1
1080 B0=+((R2*2.036)/(Q1*15.1809022))*(1.402*(X7-1)+1)/X8
1090 Z0=0.402*((X7↑2)*V7↑2*(1-X0↑2)-((R2*2.036)/(Q1*15.1809022))↑2)/X8
1100 F8=F8+1
1105 A6=A6+1
1110 IF (F8 <= A2) THEN 1125
1115 P2=((Q4-R8)*(B[1]+B[2]*K4)+R8)/Q1
1116 REM P2=B[1]+B[2]*K4+B[3]*K4↑2+B[4]*K4↑3
1120 GOTO 1200
1125 P2=B0+SQR(B0↑2-Z0)
1126 S0=P2*Q1
1127 GOTO 1200
1130 Q[A6]=K4
1135 D[A6]=(S0-R8)/(Q4-R8)
1136 REM D[A6]=P2
1140 IF (F8<A2) THEN 1165
1145 FILES POLYGA,POLYGD
1150 MAT PRINT # 1;Q
1155 MAT PRINT # 2;D
1160 CHAIN "TTR9"
1165 CHAIN "TTR1B",1,70
1200 X1=P2*(1.402/0.402)/V7
1210 X1=-X1+SQR(X1↑2+1-X0↑2)
1220 X2=SQR(X0↑2+X1↑2)
1230 Z1=1-X2↑2/(1-P2↑G0)
1231 IF (Q5=0) THEN 1260
1240 PRINT "K=";X7
1250 PRINT "    "
1260 CHAIN "TTR3"
```

# TABLE A-V

## PROGRAM "TTR3"

```
10 REM-----THE NEXT STEPS EVALUATE CONTROL VOLUME B------------------------------
20 REM-----******TTR3*****------------------------------------------------------
30 REM---------------------------------------------------------------------------
40 V2=0.98438*V0-(M5/4.25013)/W4
50 G2=3.487562189
60 B1=G2*P9*R9*22.63858979/(W4*V1)
110 X4=(4.18375/4.250125)*X0-((M5/4.250125)/(W4*V1))
120 Z2=(1-X4↑2)-2*(U3*X0-U4*X4)
130 X5=SQR(B1↑2+Z2)-B1
140 L0=(X5↑2+(X4-U4)↑2)
150 L1=((1-X2↑2)*(1-(P9/(P2*Q1))↑G0)+X2↑2-2*X0*U3+U4↑2)
160 Z3=1-L0/L1
170 E0=(M5*PI*N/360)/(0.5*W4*V1↑2*(1-(P9/Q1)↑G0))
200 R3=(P2↑G0-P4↑G0)/(1-P4↑G0)
210 X6=(X4↑2+X5↑2)↑0.5
220 R4=((X6↑2-2*X4*U4)-(X2↑2-2*X0*U3))/(U4↑2+(X6↑2-2*X4*U4))
230 DEG
240 V3=X1*V1
260 A3=ATN(V0/V3)
270 B2=ATN((V0-U1)/V3)
280 V4=X5*V1
290 V5=(V2↑2+V4↑2)↑0.5
300 V6=SQR(V0↑2+V3↑2)
310 DEG
320 A4=ATN(V2/V4)
330 B3=ATN((V2-U2)/V4)
340 M1=(X2/(1-X2↑2)↑0.5)*SQR(5)
350 M2=M1*COS(A3)
360 M3=(X6/(1-X6↑2)↑0.5)*SQR(5)
370 M4=M3*COS(A4)
380 W6=SQR(X1↑2+(X0-U3)↑2)
390 W7=SQR(X5↑2+(U4-X4)↑2)
400 P5=(1-X2↑2)↑(1/G0)
410 P6=Q1/Q3
420 H1=M5*N*PI/(360*550)
```

TABLE A-V (Cont'd)

```
430 H2=H1/(T3*Q2)
440 S0=P2*Q1
450 M7=M6/Q2
460 B4=2*C1*C3*J0
470 T7=T2*(W6↑2-U4↑2-U3↑2+1-X2↑2)
480 DEG
490 W8=W6*(COS(B2-62))
500 T8=T7-T2*W8↑2-T2*(U4↑2-U3↑2)
510 T9=T8*(P4/P2)↑G0
520 W9=SQR(ABS((T7-T9)/T2))
530 Z8=1-W7↑2/W9↑2
540 O0=1-W8↑2/W6↑2
550 U8=1/P2
580 CHAIN "UNCERT"
590 END
```

# TABLE A-VI

## PROGRAM "UNCERT"

```
10 REM      SUBPROGRAM NAME: UNCERT
20 REM      PROGRAM DISC: TTR
30 REM
40 REM      THIS SUBROUTINE IS DESIGNED TO CALCULATE THE UNCERTAINTY IN RESULTANT
50 REM      AXIAL FORCE, P1/PTO PRESSURE RATIO, AND STATOR LOSS COEFFICIENT.
60 REM
70 REM      VARIABLES ARE AS FOLLOWS:
80 REM
90 REM       N(1)= % UNCERTAINTY IN RESULTANT AXIAL FORCE
100 REM      N(2)= % UNCERTAINTY IN Z0
110 REM      N(3)= INTERMEDIATE CALCULATION= B0↑2-Z0
120 REM      N(4)= % UNCERTAINTY IN U(3)
130 REM      N(5)= % UNCERTAINTY IN PRESSURE RATIO (P1/PTO)
140 REM      N(6)= INTERMEDIATE VARIABLE X1' = 3.487562189*P2/V7
150 REM      N(7)= INTERMEDIATE VARIABLE = U(6)↑2-X0↑2+1
160 REM      N(8)= % UNCERTAINTY IN U(7)
170 REM      N(9)= % UNCERTAINTY IN X1
180 REM      N(10)= % UNCERTAINTY IN X2
190 REM      N(11)= % UNCERTAINTY IN U(12)
200 REM      N(12)= INTERMEDIATE VARIABLE = X2↑2/(1-P2↑G0)
210 REM      N(13)= % UNCERTAINTY IN Z1 (STATOR LOSS COEFFICIENT)
220 REM      N(14)=INTERMEDIATE VARIABLE= L0/L1
230 REM      N(15)= % UNCERTAINTY IN L1
240 REM      N(16)= % UNCERTAINTY IN Z3 (ROTOR LOSS COEFFICIENT)
250 REM      N(17)=R2 (RESULTANT AXIAL FORCE)
260 REM      N(18)= P2 (PRESSURE RATIO P1/PT0)
270 REM      N(19)=Z1 (STATOR LOSS COEFFICIENT)
280 REM      N(20)=Z3 (ROTOR LOSS COEFFICIENT)
290 REM
300 N[1]=1.9966/R2
310 N[2]=(0.167*0.018*(R2/Q1)*2/(V7↑2*(1-X0↑2)-0.018*(R2/Q1)))*N[1]
320 N[3]=B0↑2-Z0
330 N[4]=((2*B0↑2)/N[3])*N[1]
340 N[5]=((B0/(B0+SQR(N[3])))*N[1])↑2
350 N[5]=(N[5]+((0.5*N[3]↑0.5)/(B0+SQR(N[3]))*N[4])↑2)↑0.5
```

## TABLE A-VI (Cont'd)

```
360 N[6]=3.487562189*P2/V7
370 N[7]=N[6]↑2-X0↑2+1
380 N[8]=((2*N[6]↑2)/N[7])*N[5]
390 N[9]=(((0.5*N[7]↑0.5)/(N[7]↑0.5-N[6]))*N[8])↑2
400 N[9]=(N[9]+((N[6]/(N[7]↑0.5-N[6]))*N[5])↑2)↑0.5
410 N[10]=(X1↑2/(X0↑2+X1↑2))*N[9]
420 N[11]=2*N[10]
430 N[12]=X2↑2/(1-P2↑G0)
440 N[13]=(N[12]/(1-N[12]))*N[11]
450 N[14]=L0/L1
460 N[15]=((2*X2↑2)/L1)*N[10]
470 N[16]=(N[14]/(1-N[14]))*N[15]
480 N[17]=R2
490 N[18]=P2
500 N[19]=Z1
510 N[20]=Z3
520 FILES DATA2
530 MAT PRINT # 1,D;N
540 PRINT "UNCERTAINTY DATA IS STORED IN FILE/DATA2/RECORD"D
542 PRINT
544 PRINT
550 D=D+1
560 CHAIN "TTR4"
570 END
```

## TABLE A-VII

## PROGRAM "TTR4"

```
10 REM----------*****TTR4*****-------------------------------------------
20 REM-----THIS PROGRAM ESTIMATES STATOR VELOCITIES AND-------------------
30 REM----------LIST PRESSURE RATIOS-------------------------------------
40 I0=D0/Q1
50 I1=D1/Q1
60 I2=D2/Q1
70 I3=D3/Q1
80 I4=D4/Q1
90 I5=D5/Q1
100 I6=D6/Q1
110 I7=D7/Q1
120 I8=D8/Q1
130 I9=D9/Q1
140 J7=E3/Q1
150 Y0=SQR(1-I0↑0.2857142857)
160 Y1=SQR(1-I1↑0.2857142857)
170 Y2=SQR(1-I2↑0.2857142857)
180 Y3=SQR(1-I3↑0.2857142857)
190 Y4=SQR(1-I4↑0.2857142857)
200 Y5=SQR(1-I5↑0.2857142857)
210 Y6=SQR(1-I6↑0.2857142857)
220 Y7=SQR(1-I7↑0.2857142857)
230 Y8=SQR(1-I8↑0.2857142857)
240 Y9=SQR(1-I9↑0.2857142857)
250 Z6=SQR(1-J7↑0.2857142857)
260 L2=(Y0/(1-Y0↑2)↑0.5)*SQR(5)
270 L3=(Y1/(1-Y1↑2)↑0.5)*SQR(5)
280 L4=(Y2/(1-Y2↑2)↑0.5)*SQR(5)
290 L5=(Y3/(1-Y3↑2)↑0.5)*SQR(5)
300 L6=(Y4/(1-Y4↑2)↑0.5)*SQR(5)
310 L7=(Y5/(1-Y5↑2)↑0.5)*SQR(5)
320 L8=(Y6/(1-Y6↑2)↑0.5)*SQR(5)
330 L9=(Y7/(1-Y7↑2)↑0.5)*SQR(5)
340 O2=Y0*V1
350 O3=Y1*V1
```

TABLE A-VII (Cont'd)

```
360 O4=Y2*V1
370 O5=Y3*V1
380 O6=Y4*V1
390 O7=Y5*V1
400 O8=Y6*V1
410 O9=Y7*V1
420 J=(Y8/(1-Y8↑2)↑0.5)*SQR(5)
430 M8=(Y9/(1-Y9↑2)↑0.5)*SQR(5)
440 M9=(Z6/(1-Z6↑2)↑0.5)*SQR(5)
450 J6=Y8*V1
460 J8=Y9*V1
470 J9=Z6*V1
480 REM-----THIS SECTION CALCULATES THEOR. LOSS COEFFICIENT;SETS THEM EQUAL TO--
490 REM------ZERO FIRST SO THAT THEY ARE DEFINED------------------------------
500 E8=0
510 E9=0
550 E4=0.045
555 Q6=((1-X2↑2)↑2.48756)*X1
560 Q7=1.153E-05*(0.06333*SQR(T2)/((198.72/T2)+1))
561 Q8=(Q6*0.0807223*Q1*492*V1*1.6621)/(Q7*29.92*T2)
562 H5=12*(1/Q8↑0.2)
565 J4=2.441811-4.40721*L9+4.047785*L9↑2-1.003885*L9↑3
570 H6=1+2*(0.3051-0.2)
580 E5=E4*H6*H5*J4
590 E6=((0.0323*75*0.3554)*(1+0.962*E5))/(1-0.03*75*0.3554*E5)*E5
600 F6=(0.055/0.848+0.962*E5)/(1+0.962*E5)
610 F7=(COS(75))↑2*(F6/(1-F6))↑2
620 E7=F7/(1+F7)
630 E8=E5+E6+E7
640 B8=B2-B3
650 B2=-B2
700 J3=0.0256429-0.0005119*B2+0.0000119*B2↑2
```

## TABLE A-VII (Cont'd)

```
701 B2=-B2
710 H8=1.42835E-04*(0.06333*SQR(T8)/((198.72/T8)+1))*(29.92/S0)*(T8/492)
720 H9=W6*V1*1.0775/(H8*12)
760 T4=12*(1/H9↑0.2)
770 F9=1+2*(0.4367-0.2)
810 J4=1
820 J5=J3*T4*F9*J4
830 G8=(0.0323*B8*0.5291*COS(B3)*(1+0.962*J5))
840 X9=1-(0.03*B8*0.5291*COS(B3)*J5)
850 G8=G8/X9*J5
860 G9=(0.026/0.444+0.962*J5)/(1+0.962*J5)
870 B9=(COS(B3))↑2*(G9/(1-G9))↑2
880 U0=B9/(1+B9)
890 U5=1.13
900 U6=U5*(0.012/0.78975)/SQR(0.656/0.444)*(TAN(B2)-TAN(B3))↑1.5
910 Z7=((COS(B3))↑2/(COS(ATN((TAN(B2)+TAN(B3))/2))))
920 U6=U6*Z7
930 U7=U6/(1+U6)
940 E9=J5+G8+U0+U7
941 Z4=S0/((D7+D8)/2)
942 R6=((1+0.201*(L9↑2))↑G2)-Z4*((1+0.201*(M1↑2))↑G2)
943 R6=R6/(((1+0.201*(M1↑2))↑G2)-1)
950 CHAIN "TTR5"
960 END
```

# TABLE A-VIII

## PROGRAM "TTR5"

```
10 REM-----*****TTR5*****--------------------------------------------------------------
20 REM-----PRINT REDUCED DATA-------------------------------------------------------------
21 IF (Q5=0) THEN 770
60 WRITE (15,70)C[10],C[11]
70 FORMAT "RUN",F4.0,2X,"PT.",F4.0,"      TURBINE CONFIGURATION C"
80 PRINT
85 PRINT "TT0  =";T2
90 PRINT "PRESSURE RATIO      =";P6
92 PRINT "MEAS TURB FLOW RATE=";Z9
96 PRINT "MEAS REF FLOW RATE=";V9
100 PRINT "REF FLOW RATE       =";W5
105 PRINT "TURB NOZ RE NO.     =";Q8
110 PRINT "REF RPM             =";R0
120 PRINT "REF ROTOR MOMENT    =";M0
130 PRINT "REF HP              =";H2
140 PRINT "EFF. T-S            =";E0
150 PRINT
151 PRINT "RATIOS OF PRESSURE AND TEMPERATURES TO REFERENCE"
153 PRINT "DELTA=";Q2
154 PRINT "THETA=";(T3)↑2
156 PRINT " "
157 PRINT "LOSS COEFFICIENTS"
170 PRINT "STATOR LOSS THEOR. =";E8
180 PRINT "STATOR LOSS COEFF. =";Z1
190 PRINT "ROTOR LOSS COEFF.  =";Z3
210 PRINT "ROTOR LOSS THEOR.  =";E9
220 PRINT "---------------------------------------------------------------------------
230 PRINT "ISEN. HEAD COEFF.    =";K4
240 PRINT "TH. DEG. OF REACTION =";R3
250 PRINT "ACT. DEG. OF REACTION=";R4
260 PRINT
270 PRINT "VELOCITY TRIANGLE DATA"
280 PRINT
290 WRITE (15,300)V6,V5
300 FORMAT "V1 =",F11.5,3X,"V2 =",F11.5
310 WRITE (15,320)V3,V4
```

TABLE A-VIII (Cont'd)

```
320 FORMAT "VA1=",F11.5,3X,"VA2=",F11.5
330 WRITE (15,340)V0,V2
340 FORMAT "VU1=",F11.5,3X,"VU2=",F11.5
350 PRINT " "
360 WRITE (15,370)A3,A4
370 FORMAT "ALPHA 1=",F11.5,3X,"ALPHA 2=",F11.5
380 WRITE (15,390)B2,B3
390 FORMAT "BETA 1 =",F11.5,3X,"BETA 2 =",F11.5
400 PRINT " "
410 PRINT "MACH NO. DATA"
420 PRINT " "
430 PRINT "MACH AT 1       =";M1
440 PRINT "AXIAL MACH AT 1=";M2
450 PRINT "MACH AT 2       =";M3
460 PRINT "AXIAL MACH AT 2="M4
470 PRINT " "
480 PRINT "PRESSURE INFORMATION"
490 PRINT " "
500 PRINT "P1/PT1=";P5
510 PRINT "PT0/P1=";U8
530 PRINT "P1     =";S0
534 WRITE (15,538)04/Q1,1/U8,R8/01
538 FORMAT /,"PTIP/PTO  =",F10.6,/,"P1/PTO      =",F10.6,/,"PHUB/PTO  =",F10.6
550 PRINT " "
560 PRINT "LOSS COEFF. DUE TO OFF-DESIGN IMPINGEMENT ANGLE=";O0
570 PRINT "ROTOR LOSS COEFF. (OTHER FACTORS)=";Z8
580 PRINT "REF. STATOR MOMENT=";M7
590 PRINT " "
600 PRINT " "
610 PRINT "STATOR VELOCITIES AND MACH #'S FOLLOW (FORE TO AFT):"
620 PRINT " "
630 PRINT "()'S CORR. TO TAP HOLE #'S; SEE DRWG. #1207:"
640 PRINT " "
650 PRINT "V(6)=";O2,TAB18,"M(6)=";L2,TAB35"INLET"
660 PRINT "V(1)=";O3,TAB15,"M(1)=";L3,TAB35"INLET"
```

TABLE A-VIII (Cont'd)

```
670 PRINT "V(7)=";O4,TAB15,"M(7)=";L4,TAB35"INLET"
680 PRINT "V(2)=";O5,TAB15,"M(2)=";L5,TAB35"THROAT-M.L."
690 PRINT "V(8)=";O6,TAB15,"M(8)=";L6,TAB35"THROAT-HUB"
700 PRINT "V TH-TIP=";O7,TAB15"M TH-TIP=";L7,TAB35"THROAT-TIP"
710 PRINT "V(3)=";O8,TAB15,"M(3)=";L8,TAB35"SS-AFT"
720 PRINT "V(4)=";O9,TAB15,"M(4)=";L9,TAB35"EXIT-M.L."
730 PRINT "V(9)=";J6,TAB15,"M(9)=";J,TAB35"EXIT-HUB"
740 PRINT "V EX-TIP=";J8,TAB15,"M EX-TIP=";M8,TAB35"EXIT-TIP"
750 PRINT "V(5)=";J9,TAB15,"M(5)=";M9,TAB35"SS-AFT"
751 PRINT " "
752 PRINT " "
753 PRINT "AFTER EXPANSION LOSS DATA"
756 PRINT "AFTER EXPANSION LOSS COEF.=";R6
770 CHAIN "TTR6"
780 END
```

## TABLE A-IX

## PROGRAM "TTR6"

```
10 REM-----*****TTR6*****-------------------------------------------------------
20 REM-----STORE REDUCED DATA IN REDDAT-----------------------------------------
30 D[1]=R0
40 D[2]=W5
50 D[3]=M0
60 D[4]=E0
70 D[5]=V6
80 D[6]=V5
90 D[7]=V3
100 D[8]=V4
110 D[9]=V0
120 D[10]=V2
130 D[11]=Z1
140 D[12]=Z3
150 D[13]=R3
160 D[14]=R4
170 D[15]=K4
180 D[16]=A3
190 D[17]=A4
200 D[18]=B2
210 D[19]=B3
220 D[20]=P6
230 D[21]=M1
240 D[22]=M2
250 D[23]=M3
260 D[24]=M4
270 D[25]=H2
280 D[26]=M7
290 D[27]=O0
300 D[28]=Z8
310 D[29]=I0
320 D[30]=I1
330 D[31]=I2
340 D[32]=I3
350 D[33]=I4
```

## TABLE A-IX (Cont'd)

```
360  D[34]=I5
370  D[35]=I6
380  D[36]=I7
390  D[37]=I8
400  D[38]=I9
410  D[39]=J7
420  D[40]=U8
430  D[41]=N
440  D[42]=V8
450  D[43]=E8
460  D[44]=E9
470  D[45]=C[10]
480  D[46]=C[11]
490  D[47]=C[12]
500  D[48]=C[13]
510  D[49]=C[14]
515  D[50]=R6
516  D[51]=Q2
517  D[52]=(T3)↑2
520  D[53]=Z9
525  D[54]=V9
530  D[55]=Q8
532  D[56]=H1
534  D[57]=M5
536  D[58]=M6
538  D[59]=F4
540  D[60]=F5
542  D[61]=R2
544  D[62]=Q1
546  D[63]=T2
548  D[64]=Q3
550  D[65]=Q4
552  D[66]=S0
554  D[67]=R8
556  D[68]=Q4/Q1
```

TABLE A-IX (Cont'd)

```
558 D[69]=P2
560 D[70]=R8/Q1
562 D[71]=T2-T1
580 G1=1
590 IF G1=0 THEN 660
610 FILES REDDAT
620 MAT PRINT # 1,A7;D
630 PRINT "REDUCED DATA IS STORED IN FILE/REDDAT/RECORD"A7
640 PRINT
650 GOTO 670
660 PRINT "THIS DATA WAS NOT STORED"
670 PRINT
680 PRINT
690 CHAIN "TTR1B",1,70
692 STOP
710 REM------CHAIN OPTIONS WITH TABULATION PROGRAMS------------------------------
740 IF (A7<A2) THEN 820
741 IF (Q5=0) THEN 830
750 GET "TTR7",850,850
820 CHAIN "TTR1",1,70
830 STOP
840 END
```

## TABLE A-X

## PROGRAM "TTR7"

```
10 DIM CS[27],AS[48],PS[15,48],RS[15,27],US[15],VS[15],WS[15],XS[15],YS[15]
20 DIM ZS[15]
30 REM--------*****TTR7*****---------------------------------------------------
40 REM-------PROGRAM TO TABULATE RAW DATA FROM TTR-----------------------------
50 REM-------USING MASS MEMORY FILES-------------------------------------------
60 MAT R=ZER
70 MAT P=ZER
80 MAT U=ZER
90 MAT V=ZER
100 MAT W=ZER
110 MAT X=ZER
120 MAT Y=ZER
130 MAT Z=ZER
140 DISP "ENTER RECORD #'S:LOWEST,HIGHEST";
150 INPUT A7,A2
180 L=1
190 FOR K=A7 TO A2
220 FILES RAWDAT
230 MAT READ # 1,K;C,A
240 FOR J=1 TO 48
250 P[L,J]=A[J]
260 NEXT J
270 U[L]=C[10]
280 V[L]=C[11]
290 W[L]=C[12]
300 X[L]=C[13]
310 Y[L]=C[14]
320 Z[L]=C[16]
330 FOR I=1 TO 27
332 IF I=8 THEN 348
334 IF I=22 THEN 350
340 R[L,I]=C[I]
346 GOTO 350
348 I=I+11
350 NEXT I
360 L=L+1
370 NEXT K
```

TABLE A-X (Cont'd)

```
410 PRINT TAB40"TABLE XXII"
420 PRINT
430 PRINT TAB38"TTR INPUT DATA"
440 PRINT TAB38"--------------"
480 FOR J=1 TO 48 STEP 6
490 WRITE (15,500)J,J+1,J+2,J+3,J+4,J+5
500 FORMAT /,9X,"PORT NO.",3X,F4.0,6X,F4.0,6X,F4.0,6X,F4.0,6X,F4.0,6X,F4.0
510 PRINT "            RUN PT."
520 FOR K=1 TO L-1
530 WRITE (15,540)U[K],V[K],P[K,J],P[K,J+1],P[K,J+2],P[K,J+3],P[K,J+4],P[K,J+5]
540 FORMAT 7X,2F4.0,2X,6F10.6
550 NEXT K
560 NEXT J
580 FOR I=0 TO 27 STEP 5
582 IF I=5 THEN 604
590 WRITE (15,600)I,I+1,I+2,I+3,I+4
600 FORMAT /,9X,"CHANNEL  ",F4.0,6X,F4.0,6X,F4.0,6X,F4.0,6X,F4.0,9X,"RPM"
602 GOTO 610
604 WRITE (15,600)I,I+1,I+15,I+16,I+18
610 PRINT "            RUN PT"
620 FOR K=1 TO L-1
621 IF I=5 THEN 634
622 IF I#0 THEN 630
624 I=1
630 WRITE (15,640)U[K],V[K],R[K,I],R[K,I+1],R[K,I+2],R[K,I+3],R[K,I+4],Z[K]
632 GOTO 650
634 WRITE (15,640)U[K],V[K],R[K,I+1],R[K,I+2],R[K,I+15],R[K,I+16],R[K,I+18],Z[K]
640 FORMAT 7X,2F4.0,5F10.6,F10.0
650 NEXT K
652 IF I#1 THEN 656
654 I=0
656 IF I#5 THEN 660
658 I=I+13
660 NEXT I
680 PRINT
690 PRINT
760 GET "TTR8"
770 STOP
780 END
```

# TABLE A-XI

## PROGRAM "TTR8"

```
10 DIM DS[71],GS[15,71]
20 REM----------*****TTR8*****-------------------------------------------------
30 REM----------PROGRAM TO TABULATE REDUCED DATA FOR TTR------------------------
40 REM----------USING MASS MEMORY FILES-----------------------------------------
50 PRINT
60 PRINT
70 PRINT
80 PRINT
90 PRINT
100 PRINT
110 R=18
120 S=19
130 T=13
140 U=14
150 DISP "ENTER LOWEST,HIGHEST REC#";
160 INPUT A7,A2
170 I=1
180 FOR K=A7 TO A2
190 FILES REDDAT
200 MAT READ # 1,K;D
210 FOR J=1 TO 71
220 G[I,J]=D[J]
230 NEXT J
240 I=I+1
250 NEXT K
260 M=I-1
270 DISP "ENTER RUN #";
280 INPUT Y
290 PRINT TAB36"TABLE IV"
300 WRITE (15,310)Y
310 FORMAT 30X,"RUN",F3.0,2X,"REDUCED DATA"
320 PRINT
330 PRINT TAB32"VELOCITY TRIANGLE"
340 FORMAT 7X,"PT.",6X,"V1",8X,"V2",8X,"VA1",7X,"VA2",7X,F10.6
350 WRITE (15,340)"VU1","        VU2"
```

# TABLE A-XI (Cont'd)

```
360 FOR I=1 TO M
370 WRITE (15,380)I,G[I,5],G[I,6],G[I,7],G[I,8],G[I,9],G[I,10]
380 FORMAT 7X,F3.0,6F10.1
390 NEXT I
400 PRINT "          ----------------------------------------------------------"
410 PRINT TAB25"MACH NUMBERS";TAB56"ANGLES"
420 FORMAT 7X,"PT.",5X,"M1",5X,"MA1",6X,"M2",5X,"MA2",5X,"A1",6X,"A2",2X,F6.2
430 WRITE (15,420)"  B1","      B2"
440 FOR I=1 TO M
450 WRITE (15,460)I,G[I,21],G[I,22],G[I,23],G[I,24],G[I,16],G[I,17],G[I,R],G[I,S
460 FORMAT 7X,F3.0,4F8.3,4F7.1
470 NEXT I
480 PRINT "          ----------------------------------------------------------"
490 PRINT TAB37"LOSSES"
500 FORMAT 7X,"PT.",5X,"ZS",6X,"ZSTH",6X,"ZR",6X,"ZRTH",6X,"ZR*",5X,"ZI",7X,"Y"
510 WRITE (15,500)
520 FOR I=1 TO M
530 WRITE (15,540)I,G[I,11],G[I,43],G[I,12],G[I,44],G[I,28],G[I,27],G[I,50]
540 FORMAT 7X,F3.0,5F9.4,E10.1,F7.3
550 NEXT I
560 PRINT "          ----------------------------------------------------------"
570 PRINT " "
580 PRINT " "
590 PRINT " "
600 PRINT " "
610 PRINT " "
620 PRINT " "
630 PRINT " "
640 PRINT " "
650 PRINT " "
660 WRITE (15,310)Y
670 PRINT " "
680 FORMAT 7X,"PT.",3X,"P.R.",3X,"STPR",6X,"H.P.",7X,"RTM",7X,"STM",F5.1
690 WRITE (15,680)"        AXF","             CLF"
700 FOR I=1 TO M
```

## TABLE A-XI (Cont'd)

```
710 WRITE (15,720)I,G[I,20],G[I,40],G[I,56],G[I,57],G[I,58],G[I,59],G[I,60]
720 FORMAT 7X,F3.0,2F7.2,1X,F9.2,4F11.2
730 NEXT I
740 PRINT "           ------------------------------------------------------------"
750 FORMAT 7X,"PT.",3X,"MW-DOT",7X,"PTO",5X,"TTO",7X,"PHD",6X,"P-TIP",F7.1
760 WRITE (15,750)"       P1","        P-HUB"
770 FOR I=1 TO M
780 WRITE (15,790)I,G[I,53],G[I,62],G[I,63],G[I,64],G[I,65],G[I,66],G[I,67]
790 FORMAT 7X,F3.0,F11.5,F9.3,F8.1,4F10.3
800 NEXT I
810 PRINT "           ------------------------------------------------------------"
820 FORMAT 7X,"PT.",3X,"PTIP/PTO",3X,"P1/PTO",3X,"PHUB/PTO",4X,"KIS",F3.1
830 WRITE (15,820)"      TURB RE","    DEL T","       ETA"
840 FOR I=1 TO M
850 WRITE (15,860)I,G[I,68],G[I,69],G[I,70],G[I,15],G[I,55],G[I,71],G[I,4]
860 FORMAT 7X,F3.0,4F10.3,F10.0,F10.2,F8.3
870 NEXT I
880 PRINT "           ------------------------------------------------------------"
890 FORMAT 7X,"PT.",3X,"DELTA",3X,"THETA",4X,"RHP",6X,"RMW-DOT",5X,"RRTM",F8.2
900 WRITE (15,890)"        RSTM","          RN"
910 FOR I=1 TO M
920 WRITE (15,930)I,G[I,51],G[I,52],G[I,25],G[I,54],G[I,3],G[I,26],G[I,1]
930 FORMAT 7X,F3.0,2F8.3,F9.3,F11.5,2F11.3,F10.0
940 NEXT I
950 PRINT "           ------------------------------------------------------------"
960 FORMAT 7X,"PT.",3X,"RTH",4X,"REFF",6X,"RAF",7X,"RPM"
970 WRITE (15,960)
980 FOR I=1 TO M
990 WRITE (15,1000)I,G[I,T],G[I,U],G[I,61],G[I,41]
1000 FORMAT 7X,F3.0,2F7.2,F10.2,F10.0
1010 NEXT I
1015 PRINT "      ----------------------------------------------------------------"
1017 PRINT
1020 PRINT TAB30"NOZZLE PRESSURE RATIOS"
1030 FORMAT 7X,"PT.",5X,"P1",6X,"P2",6X,"P3",6X,"P4",6X,"P5",6X,"P6",6X,F9.2
```

## TABLE A-XI (Cont'd)

```
1040 WRITE (15,1030)"P7"
1050 FOR I=1 TO M
1060 WRITE (15,1070)I,G[I,30],G[I,32],G[I,35],G[I,36],G[I,39],G[I,29],G[I,31]
1070 FORMAT 7X,F3.0,7F8.3
1080 NEXT I
1090 PRINT "         ---------------------------------------------------------
1100 FORMAT 7X,"PT.",5X,"P8",6X,"P9"
1110 WRITE (15,1100)
1120 FOR I=1 TO M
1130 WRITE (15,1140)I,G[I,33],G[I,37]
1140 FORMAT 7X,F3.0,2F8.3
1150 NEXT I
1160 STOP
1170 PRINT "         ------------------DATA TABULATION COMPLETE----------------
1180 DISP "CHAIN WITH TTR1";
1190 WAIT 3000
1200 GET "TTR1"
1210 STOP
1220 END
```

## TABLE A-XII

## PROGRAM "TTR11"

```
10 DIM NS[20],GS[15,28]
20 REM      PROGRAM NAME: TTR11
30 REM      PROGRAM DISC: TTR
40 REM
50 REM      PROGRAM DISCRIPTION: THIS PROGRAM IS DESIGNED TO BATCH PROCESS
60 REM      THE UNCERTAINTY DATA FROM RIG RUNS.
70 REM
80 DISP "ENTER LOWEST/HIGHEST RECORD #";
90 INPUT A7,A2
100 I=1
110 FOR K=A7 TO A2
120 FILES DATA2
130 MAT READ # 1,K;N
140 FOR J=1 TO 20
150 G[I,J]=N[J]
160 NEXT J
170 G[I,21]=N[1]*N[17]
180 G[I,22]=N[1]*100
190 G[I,23]=N[18]*N[15]
200 G[I,24]=N[5]*100
210 G[I,25]=N[13]*N[19]
220 G[I,26]=N[13]*100
230 G[I,27]=N[20]*N[16]
240 G[I,28]=N[16]*100
250 I=I+1
260 NEXT K
270 M=I-1
280 DISP "ENTER RUN #";
290 INPUT Y
300 PRINT
310 PRINT
320 PRINT TAB36"TABLE II"
330 WRITE (15,340)Y
340 FORMAT 28X,"RUN",F3.0,2X,"UNCERTAINTY DATA"
357 PRINT
```

## TABLE A-XII (Cont'd)

```
360 FORMAT 7X,"PT.",5X,"RAF",7X,"+/-",5X,"% ERROR",5X,"P1/PTO",7X,"+/-",6X,F8.0
370 WRITE (15,360)"% ERROR"
380 FOR I=1 TO M
390 WRITE (15,400)I,G[I,17],G[I,21],G[I,22],G[I,18],G[I,23],G[I,24]
400 FORMAT 6X,F3.0,F10.2,2F10.3,2F12.4,F10.3
410 NEXT I
420 PRINT
430 PRINT
440 FORMAT 7X,"PT.",6X,"Z1",6X,"+/-",6X,"% ERROR",8X,"Z3",8X,"+/-",6X,"% ERROR"
450 WRITE (15,440)
460 FOR I=1 TO M
470 WRITE (15,480)I,G[I,19],G[I,25],G[I,26],G[I,20],G[I,27],G[I,28]
480 FORMAT 6X,F3.0,2F10.4,F10.2,2F12.4,F10.2
490 NEXT I
500 PRINT
510 PRINT
520 PRINT
530 STOP
540 END
```

## TABLE A-XIII

## VARIABLES ADDED/MODIFIED TO THE REDUCTION PROGRAMS

| | |
|---|---|
| T1 | Expression for turbine outlet temperature |
| Z9 | Expression for computed flow rate |
| V9 | Expression for computed referred flow rate |
| W0 | Modified in meaning - was equal to $\dot{W}$ based on a constant 1.02 lbm/sec flow rate in previous programs (see Ref. 1). Now is equivalent to Z9, computed $\dot{W}$. |

## TABLE A-XIV

## PLOT ROUTINES

| PROGRAM | |
|---|---|
| KPLOT | $\zeta_S/\zeta_R$ vs. $K_{is}$ |
| KPLOT1 | Referred rotor torque vs. referred RPM |
| KPLOT2 | $\eta_{TS}$ vs. referred RPM |
| KPLOT3 | $\eta_{TS}$ vs. axial spacing (in) |
| KPLOT4 | $\eta_{TS}$ vs. $K_{is}$ |
| KPLOT5 | Referred HP vs. referred RPM |
| KPLOT6 | $\zeta_R$ vs. axial spacing (in) |
| KPLOT7 | After expansion (Y) vs. pressure ratio (stator) |
| KPLOT8 | Loss coefficient (Y) vs. $K_{is}$ |
| KPLOT9 | Y vs. $P_1/P_{exit}$ |
| PLOT0 | Stator pressure ratio ($P_{t_o}/P_1$) vs. $K_{is}$ |
| BPLOT | Actual/theoretical degree of reaction vs. $K_{is}$ |
| BPLOT1 | $\dot{W}_{ref}$ vs. $K_{is}$ |
| BPLOT2 | Incident loss coefficient vs. $K_{is}$ |
| BPLOT5 | Max efficiency/Max. global efficiency<br>vs.<br>Axial spacing/rotor blade height |

| | |
|---|---|
| BPLOT6 | $\zeta_S$ vs. stator pressure ratio |
| TPLOT3 | Rotor shroud pressure ratio vs. shroud tap points |
| TPLOT4 | Stator suction side pressure ratio vs. stator nozzle tap |
| TPLOT5 | Pressure ratio ($P_1/P_{t_o}$) vs. $K_{is}$ |
| TPLOT6 | Resultant axial force vs. $K_{is}$ |
| TPLOT7 | Referred stator torque vs. $K_{is}$ |

# TABLE A-XV

## PROGRAM "RPMSUR"

```
10 REM      PROGRAM NAME: RPMSUR
20 REM
30 REM*****PROGRAM TO EXAMINE TURBINE RPM VARIATIONS WITH TIME******************
40 REM
50 REM
60 PRINT
70 PRINT
80 DIM MS[3,120],NS[120],PS[120],QS[120],CS[3]
90 MAT M=ZER
100 MAT N=ZER
110 MAT P=ZER
120 MAT Q=ZER
130 MAT C=ZER
140 PRINT "CHECK LINES 290,310-400 FOR PROPER SCALING FACTORS"
150 PRINT
160 PRINT
170 DISP "READY PLOTTER WITH PAPER";
180 STOP
190 DISP "ENTER NEXT RECORD #,DATE (MO,DA,YR)";
200 INPUT E1,C[1],C[2],C[3]
210 GOSUB 290
220 DISP "PRESS CONT WHEN READY TO RECORD RPM PTS";
230 STOP
240 GOSUB 680
250 GOSUB 900
260 GOSUB 1000
270 STOP
280 END
290 SCALE -30,390,17500,20500
300 LABEL (*,1.2,1.7,0,17/25)
310 X0=20
320 X1=0
330 X2=360
340 X3=20
350 X4=20
```

## TABLE A-XV (Cont'd)

```
360 Y0=200
370 Y1=17700
380 Y2=20300
390 Y3=17900
400 Y4=200
410 XAXIS Y1,X0,X1,X2
420 YAXIS X2,Y0,Y1,Y2
430 YAXIS X1,Y0,Y1,Y2
440 XAXIS Y2,X0,X1,X2
450 REM*****LABEL AXES**********************************************************
460 FOR X9=X3 TO X2 STEP X4
470 PLOT X9,Y1
480 CPLOT -2,-1
490 FORMAT F5.0
500 LABEL (*)X9
510 NEXT X9
520 FOR Y9=Y3 TO Y2 STEP Y4
530 PLOT X1,Y9
540 CPLOT -6,-0.3
550 FORMAT F5.1
560 LABEL (*)Y9
570 NEXT Y9
580 REM*****NAME AXES***********************************************************
590 PLOT (X1+X2)/2,Y1,1
600 CPLOT -13,-3
610 LABEL (*)"SAMPLES (ABOUT 330 PER MIN)"
620 LABEL (*,1.2,1.7,PI/2,17/25)
630 PLOT X1,(Y1+Y2)/2,1
640 CPLOT -2,5
650 LABEL (*)"RPM"
660 RETURN
670 END
680 REM*****SUBROUTINE TO RECORD RPM********************************************
690 DIM S$[3]
700 FORMAT 4B
```

TABLE A-XV (Cont'd)

```
710 FORMAT F3.0
720 FORMAT 3B
730 OUTPUT (13,700)256,20,768,512;
740 CMD "?D%","PF4G5S6"
750 CMD "?D!"
760 OUTPUT (13,710)16
770 FOR J=1 TO 3
780 FOR I=1 TO 120
790 CMD "?D%"
800 OUTPUT (13,720)256,8,512;
810 CMD "?E$"
820 ENTER (13,*)Y
830 Y=Y*2
840 M[J,I]=Y
850 NEXT I
860 NEXT J
865 CMD "?D!","C"
870 RETURN
880 END
890 REM      SUBROUTINE TO PLOT RPM POINT
900 L=1
910 FOR J=1 TO 3
920 FOR I=1 TO 120
930 LABEL (*,1,1,0,1)
940 PLOT L,M[J,I]
950 L=L+1
960 NEXT I
970 NEXT J
980 RETURN
990 END
1000 REM*****SUBROUTINE TO STORE RPM DATA***************************************
1010 FILES RPMSTO
1020 FOR I=1 TO 120
1030 N[I]=M[1,I]
1040 P[I]=M[2,I]
1050 Q[I]=M[3,I]
```

TABLE A-XV (Cont'd)

```
1060 NEXT I
1070 MAT PRINT # 1,E1;N
1080 MAT PRINT # 1,E1+1;P
1090 MAT PRINT # 1,E1+2;Q,C
1100 WRITE (15,1110)E1,E1+1,E1+2
1110 FORMAT "THE RAW DATA IS STORED ON RPMSTO RECORD #",F3.0,",",F3.0,"AND",F3.0
1120 E1=E1+3
1130 RETURN
1140 END
```

## TABLE A-XVI

## PROGRAM "TERRY7"

```
10 REM PROGRAM NAME:  TERRY7
20 REM PROGRAM DISCRIPTION: DESIGNED TO TABULATE, CALCULATE, AND COMPARE ACTUAL
30 REM              DELTA TEMPS ACROSS THE STAGE WITH DELTA TEMPS NECESSARY TO
40 REM              PRODUCE THE CALCULATED HORSEPOWER.  DELTA TEMP OF THE H.P. IS
50 REM              COMPUTED USING REFERRED H.P. AND REFERRED MASS FLOW.
60 REM
70 DIM DS[71],G[15,71],X[15,2]
71 PRINT
72 PRINT
73 PRINT TAB34"TABLE XVI"
74 PRINT
75 PRINT TAB20"TEMPERATURE DROP CALCULATED FROM THE"
76 PRINT TAB21"MEASURED POWER AND MEASURED VALUES"
77 PRINT
80 DISP "ENTER LOWEST, HIGHEST RECORD #";
90 INPUT A7,A2
100 I=1
110 FOR K=A7 TO A2
120 FILES REDDAT
130 MAT READ # 1,K;D
140 FOR J=1 TO 71
150 G[I,J]=D[J]
160 NEXT J
170 X[I,1]=G[I,25]*G[I,52]/((778.16/550)*G[I,54]*0.24)
175 X[I,2]=G[I,71]-X[I,1]
180 I=I+1
190 NEXT K
200 M=I-1
230 PRINT TAB35"RUN "G[M,45]
240 PRINT
250 PRINT
260 FORMAT 7X,"PT.",4X,"H.P.",4X,"R-H.P.",2X,"RMW-DOT",4X,"TTO",F5.2
270 WRITE (15,260)"    DEL T","  C-DEL T","  DIFF"
280 PRINT
290 FOR I=1 TO M
```

TABLE A-XVI (Cont'd)

```
300 WRITE (15,310)I,G[I,56],G[I,25],G[I,54],G[I,63],G[I,71],X[I,1],X[I,2]
310 FORMAT 6X,F3.0,2F9.2,F10.5,3F8.1,F7.1
320 NEXT I
330 PRINT
340 PRINT
350 PRINT
360 PRINT
370 PRINT
380 STOP
390 END
```

## TABLE A-XVII

## PROGRAMS USED FOR ACQUIRING, MODIFYING, OR REDUCING DATA

| PROGRAM | USE |
|---|---|
| SCAMOD | Acquires raw data for turbine performance tests |
| TTRIB | Recalls raw data from storage. Assigns scaling factors. |
| TTR2 | Calculates $\dot{W}_{LAB}$, $\dot{W}$, $\dot{W}_{ref}$, and calculates parameters in stator control volume ($\zeta_S$, etc.) |
| TTR3 | Calculates parameters in rotor control volume ($\zeta_R$, etc.) |
| UNCERT | Calculates uncertainties in RAF, $P_1/P_{Z0}$, $\zeta_S$, and $\zeta_R$ |
| TTR4 | Calculates stator velocities and theoretical loss coefficients |
| TTR5 | Prints out results for each reduced data point |
| TTR6 | Stores reduced data |

| | |
|---|---|
| TTR7 | Tabulates raw data |
| TTR8 | Tabulates reduced data |
| TTR11 | Tabulates uncertainty data |
| RPMSUR | Takes 360 RPM samples at a rate of 330/min and stores them on a set of 3 sequential record numbers |
| TERRY7 | Compares actual and computed temperature differences across the stage based on horsepower calculations |

## TABLE A-XVIII

## WAVEFORM ANALYSIS PROGRAM MODIFICATIONS TO ACCEPT TIME DOMAIN DATA

| Statement # | Statement |
|---|---|
| 2520 (Current Program Statement OK) | OFF ERROR |
| 2521 (Begin Modification) | FOR I = 1 TO 128 |
| 2530 | READ #1; Real(I) |
| 2531 | NEXT I |
| 2532 | FOR I = 1 TO 128 |
| 2533 | READ #1; Imag(I) |
| 2534 | NEXT I |
| 2540 (This Program Statement OK) | IF Conv $[1,1]="N" THEN REWIND B$ |

## TABLE A-XIX

## DATA FILES AND PROGRAMS USED FOR FOURIER ANALYSIS

| Data/Program | Where Stored (Note 1) | |
|---|---|---|
| 15000 RPM (DATA) | "TERRY2" | (Raw Form - 256 Data Points) |
| | "AVG2" | (Averaged Form - 256 Data Points)<br>See Note 2 |
| 19000 RPM (DATA) | "TERRY1" | (Raw Form - 256 Data Points) |
| | "AVG1" | (Averaged Form - 256 Data Points)<br>See Note 2 |
| 40 Point Power Correlation Data | "TERRY3" | (Before referring) |
| FIXER (Program to take out the 'DC' components from raw RPM data and store on a different data file) | TPL Library Tape #1 | |

Note 1: All data files listed in this table are stored on TPL Library #1 Tape (Not to be confused with the H.P. Library tapes.)

Note 2: The data could only be analyzed in powers of 2; therefore all 359 points could not be used and only the first 256 points were analyzed on each RPM data set.

## TABLE A-XX

## RAW DATA ANOMALIES

| Run | Point | Pressure Port | Action |
|---|---|---|---|
| 13 | 1 | 8 | Deleted A(8) from line 1080 in TTR1B for points 1 and 8 |
| 13 | 8 | 8 | |
| 15 | 2-8 | $\Delta P_{noz}$ (see Note 1) | Used point 1 value for all points in line 1090 of TTR1B |

Note 1: $\Delta P_{noz}$ is recorded on channel 27 through scanner number 1 (see Appendix B).

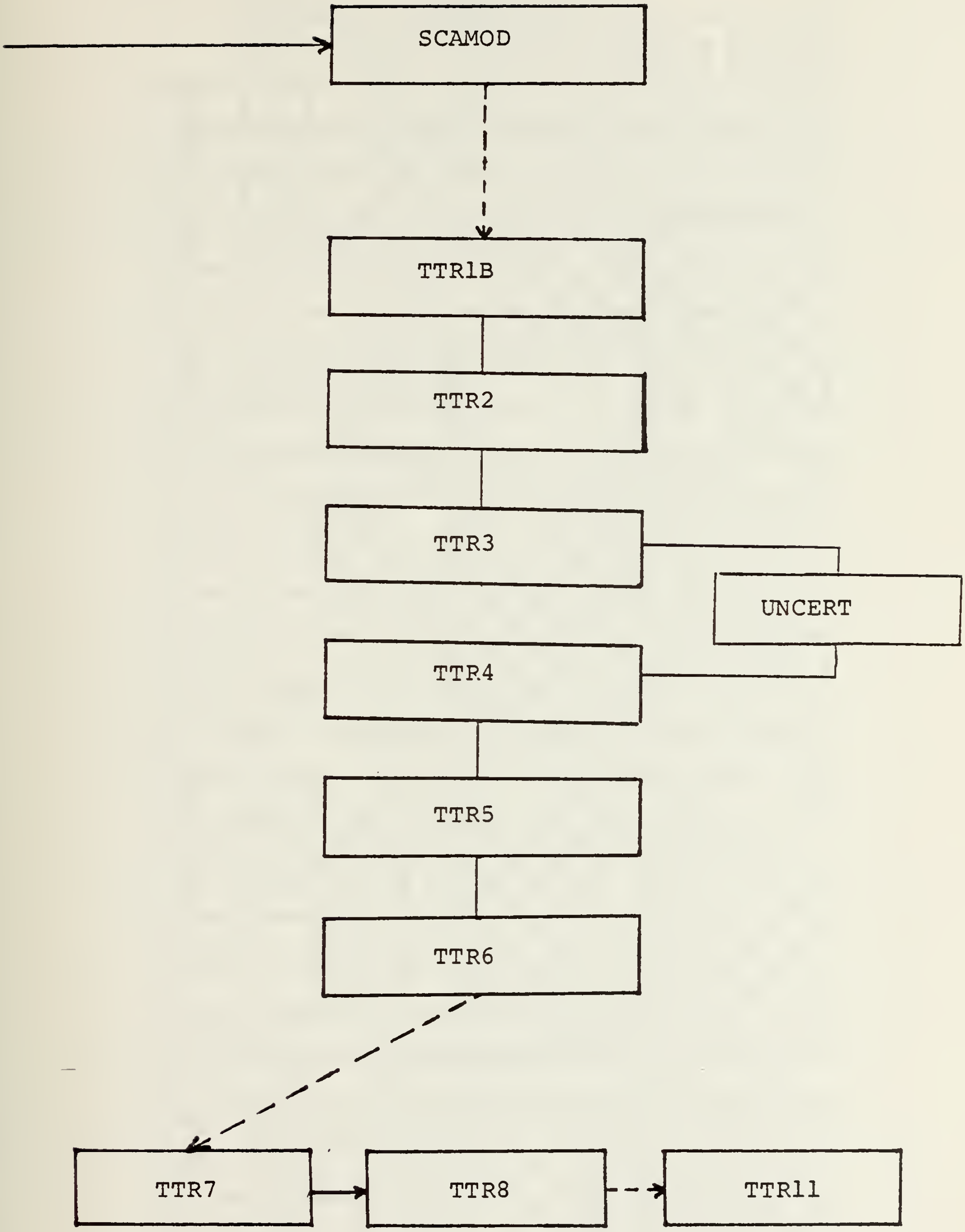


FIGURE A-1. Acquisition, Reduction and Processing Sequence

| | ARRAY | SIMPLE VARIABLE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SUBSCRIPT | | | | | | | | | | |
| | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| A | / | | / | / | / | / | / | / | / | / | / | / |
| B | / | | / | / | / | / | / | / | / | / | / | / |
| C | / | | / | / | / | / | / | / | / | / | / | / |
| D | / | / | / | / | / | / | / | / | / | / | / | / |
| E | | | / | / | | / | / | / | / | / | / | / |
| F | | | / | / | / | / | / | / | / | / | / | / |
| G | / | | / | / | / | | | | / | / | / | / |
| H | | / | / | / | / | | | / | / | | / | / |
| I | | / | / | / | / | / | / | / | / | / | / | / |
| J | | / | / | | / | | / | / | / | / | / | / |
| K | | / | / | / | / | / | / | / | / | / | / | |
| L | | / | / | / | / | / | / | / | / | / | / | / |
| M | | | / | / | / | / | / | / | / | / | / | / |
| N | / | | / | / | / | / | / | / | / | / | / | / |
| O | | | / | / | / | / | / | / | / | / | / | / |
| P | / | | / | / | / | | / | / | / | / | | / |
| Q | / | / | / | / | / | / | / | / | / | / | / | |
| R | / | / | / | / | / | / | / | | / | | / | / |
| S | | / | / | / | / | / | / | / | / | / | / | / |
| T | | / | / | | / | / | / | / | / | / | / | / |
| U | / | | / | / | / | / | / | / | / | / | / | / |
| V | / | | / | / | / | / | / | / | / | / | / | |
| W | / | / | / | / | / | / | / | / | / | / | / | / |
| X | / | | / | / | / | / | / | / | / | / | / | / |
| Y | / | | / | / | / | / | / | / | / | / | / | / |
| Z | / | / | / | / | / | / | / | | / | / | / | |

FIGURE A-2. ARRAYS AND VARIABLES USED

# APPENDIX B

# TEST RIG MEASUREMENTS AND SCALING FACTORS

The test rig measurements were obtained using the test instrumentation of Figure 5. The 46 recorded scanivalve ports and corresponding quantities are given in Table B-I. The channel numbers and corresponding quantities for the 15 other recorded parameters are also listed. The scaling factors applied to the raw data voltages to obtain the proper engineering units are given in Table B-II.

# TABLE B-I

# TEST RIG MEASUREMENTS

## Pressures

| Scanivalve Port Number (Scanner 1) | Quantity |
|---|---|
| 1 | Atmospheric |
| 2 | Calibration Reference |
| 3 | Flow Nozzle (upstream flange) |
| 4 | Flow Nozzle (downstream flange) |
| 5 | Labyrinth Plenum (Fig. 2) |
| 6 | Stator Total Inlet (Fig. 3) |
| 7 | " |
| 8 | " |
| 9 | " |
| 10 | " |
| 11 | Hood |
| 12 | Stator Tap #1 (Fig. 7) |
| 13 | Stator Tap #2 (Fig. 7) |
| 14 | Stator Tap #3 (Fig. 7) |
| 15 | Stator Tap #4 (Fig. 7 |
| 16 | Stator Tap #5 (Fig. 7) |
| 17 | Stator Tap #6 (Fig. 7 |
| 18 | Stator Tap #7 (Fig. 7) |
| 19 | Stator Tap #8 (Fig. 7) |
| 20 | Stator Tap #9 (Fig. 7) |
| 21 | Stator Exit Hub (Fig. 3) |
| 22 | Stator Tip (above Tap #8) |
| 23 | Stator Tip (above Tap #9) |
| 24 | Stator Exit Tip (Fig. 3) (See Note 1) |
| 25 | Atmospheric (spare) |
| 26 | Calibration Reference (spare) |
| 27 | Labyrinth (spare) |
| 28 | Stator Inlet Static |
| 29 through 46 | Rotor Shroud (spaced at 1 inch between centers along shroud inclined face |

TABLE B-I (Cont'd)

Other Channels

| Scanner Number | Scanner Channel | Quantity |
|---|---|---|
| 2 | 00 | Air supply temperature |
| | 01 | Flow nozzle temperature |
| | 02 | Inlet plenum temperature |
| | 03 | Closure volume temperature |
| | 04 | Stator total inlet temperature |
| | 05 | Turbine outlet total temperature |
| | 06 | Labyrinth temperature |
| 1 | 16 | RPM |
| | 20 | Stator axial force |
| | 21 | Closure plate force |
| | 23 | Dynamometer torque |
| | 24 | Stator torque |
| | 25 | Atmospheric pressure |
| | 26 | Flow nozzle pressure |
| | 27 | Flow nozzle $\Delta P$ |

Note 1: This channel is sampled 30 times and averaged prior to storage to reduce unsteadiness.

## TABLE B-II

## SCALING FACTORS

| Parameter | Channel Number | Scaling Factor |
|---|---|---|
| Pressure (all scanivalve ports) | 1<br>(Scanner #1) | Conversion to in Hg x 1000 |
| Temperatures | 00-06<br>(Scanner #2) | Polynomial regression formula to °F + 460 to °R |
| RPM | 16<br>(Scanner #1) | x 2 |
| Axial Force | 20<br>(Scanner #1) | x $10^5$ |
| Closure Force | 21<br>(Scanner #1) | x $10^4$ |
| Dynamometer Torque | 23<br>(Scanner #1) | x $10^5$ |
| Stator Torque | 24<br>(Scanner #1) | x $10^5$ |
| Atmospheric Pressure | 25<br>(Scanner #1) | x $10^4$ |
| Flow Nozzle Pressure | 26<br>(Scanner #1) | x $10^4$ |
| Flow Nozzle $\Delta P$ | 27<br>(Scanner #1) | x $10^4$ |

# APPENDIX C

## UNCERTAINTY ANALYSIS

An uncertainty analysis was conducted on four key inter-stage parameters, i.e., stator exit pressure ratio ($P_1/Pt_o$), resultant axial force (RAF), stator loss coefficient ($\zeta_S$), and rotor loss coefficient ($\zeta_R$). The analysis was done in accordance with the principles contained in Ref. (16). The following formulas were used repeatedly to develop the propagation formulas for each intermediate parameter of interest:

Note: "U" denotes uncertainty interval throughout this appendix.

$$\text{Desired form:} \quad \frac{U_R}{R} = \left[\left(\frac{\partial \ln V_i}{\partial \ln R}\,\frac{U_{V_i}}{V_i}\right)^2 + \left(\frac{\partial \ln w_i}{\partial \ln R}\,\frac{U_{w_i}}{w_i}\right)^2\right]^{1/2}$$

where $v_i$ and $w_i$ are independent variables and $R = f(v_i, w_i)$.

1. If $R = x \pm y$ then

$$\frac{\partial \ln x}{\partial \ln R} = \frac{x}{x \pm y} \quad \text{and} \quad \frac{\partial \ln y}{\partial \ln R} = \frac{-y}{x \pm y}$$

and

$$U_R = [(U_x)^2 + (\pm U_y)^2]^{1/2}$$

2. If $R = 1 - y^n$, then

$$\frac{U_R}{R} = \frac{ny^n}{1 - y^n} \frac{U_y}{y}$$

3. If $R = x + y^n$, then

$$\frac{U_R}{R} = [(\frac{x}{x + y^n} \cdot \frac{U_x}{x})^2 + (\frac{ny^n}{x + y^n} \cdot \frac{U_y}{y})^2]^{1/2}$$

4. If $R = xy^n + z^m$, then

$$\frac{U_R}{R} = [(\frac{xy^n}{R} \cdot \frac{U_x}{x})^2 + (\frac{nxy^n}{R} \cdot \frac{U_y}{y})^2 + (\frac{mz^m}{R} \cdot \frac{U_z}{z})^2]^{1/2}$$

5. If $R = V^n$, then

$$\frac{U_R}{R} = v \frac{U_v}{V}$$

6. If $R = ax \pm by$, then

$$U_R = [(a\ U_x)^2 + (b\ U_y)^2]^{1/2}$$

The following development is divided into five sections. In each of four sections, one reduced parameter uncertainty is calculated. A simplified analysis section follows.

Table C-I contains the definition of terms used in the analysis. Symbols used in this appendix are consistent with those used in the reduction program in Appendix A. The

assumed uncertainty intervals in the raw data parameters of interest are given in Table C-II and are consistent with those given in Ref. 1. The point chosen for analysis was run 10 point 1. Pertinent raw data, and intermediate calculation data are given in Table C-III. The uncertainty approximation formulas developed here are summarized in Table C-IV.

## C.1 RESULTANT AXIAL FORCE (R2) UNCERTAINTY

Using Eqn C(4) in Reference 1, the resultant axial force is given by

$$R2 = F4 + F5 + 0.491159(F3 - F2 - F0')$$

where

$$F0' = F0 + F1 + A8 + A9 + B5 + B6 + B7$$

and

$$F0 = N8(0.25) + N9(0.50) + 01(0.50)$$

The uncertainty in R2 is then calculated by first calculating the uncertainty in each of the terms in the above expressions. These calculations follow:

$$U_{F0} = [(0.25 \times .05)^2 + (.5 \times .04)^2 + (.5 \times .04)^2]^{1/2}$$

$$= .03$$

since,

$$F1 = 0.51(S3 + S4 + S5)$$

$$U_{F1} = 0.51[(U_{S3})^2 + (U_{S4})^2 + (U_{S5})^2]^{1/2}$$

$$= 0.51[3(.04)^2]^{1/2}$$

$$= .0353$$

and since

$$A8 = 0.51(S6 + S7 + S8)$$

$$U_{A8} = 0.51[(U_{S6})^2 + (U_{S7})^2 + (U_{S8})^2]^{1/2}$$

$$= 0.51[3(.04)^2]^{1/2}$$

$$= .0353$$

Also, since

$$A9 = 0.52[S9 + N0 + N1]$$

$$U_{A9} = [(U_{S9})^2 + (U_{N0})^2 + (U_{N1})^2]^{1/2}$$

$$= 0.52[3(.04)^2]^{1/2}$$

$$= .036$$

Similarly,

$$B5 = 0.52N2 + 0.52N3 + 0.53N4$$

$$U_{B5} = [(0.52\,U_{N2})^2 + (0.52\,U_{N3})^2 + (0.53\,U_{N4})^2]^{1/2}$$

$$= [(0.52 \times .04)^2 + (0.52 \times .04)^2 + (0.53 \times .04)^2]^{1/2}$$

$$= .03625$$

$$B6 = 0.71\,N5 + 4.80999(N6 + N7)$$

$$U_{B6} = [(0.71\,U_{N5})^2 + (4.80999\,U_{N6})^2 + (4.8099\,U_{N7})^2]^{1/2}$$

$$= [(0.71 \times .04)^2 + (4.80999 \times .04)^2 \times 2]^{1/2}$$

$$= .2736$$

Note here the order of magnitude difference in the uncertainties of N6 and N7 compared with the other parameters.

Continuing,

$$B7 = 1.897 \times Q4$$

$$U_{B7} = 1.897\,U_{Q4} = .07588$$

Therefore,

$$U_{F0'} = [(U_{F0})^2 + (U_{F1})^2 + (U_{A8})^2 + (U_{A9})^2 + (U_{B5})^2 + (U_{B6})^2 + (U_{B7})^2]^{1/2}$$

$$= [(.03)^2 + (.0353)^2 + (.0353)^2 + (.036)^2 + (.03625)^2 + (.2736)^2 + (.07588)^2]^{1/2}$$

$$= .2943$$

Similarly,

$$F2 = 47.66118069 \times R8$$

$$U_{F2} = 47.66118069\ U_{R8} = 47.66118069 \times .04$$

$$= 1.9064$$

$$F3 = 82.51589456 \times Q3$$

$$U_{F3} = 82.51589456\ U_{Q3}$$

$$= 82.51589456 \times .04$$

$$= 3.3006$$

Finally,

$$U_{R2} = [(U_{F4})^2 + (U_{F5})^2 + (.491159\ U_{F3})^2 + (-.491159\ U_{F2})^2 + (-.491159\ U_{F0'})^2]^{1/2}$$

$$U_{R2} = [(.48)^2 + (.48)^2 + (.491159 \times 3.3006)^2 + (-.491159 \times 1.9064)^2 + (-.491159 \times .2943)^2]^{1/2}$$

$$= \underline{1.9966 \text{ lbf}}$$

Note here the predominant effects of Q3 and R8, i.e., the hood pressure and stator exit pressure "hub #3" respectively.

Therefore, the potential % error in the resultant axial force is equal to

$$\frac{U_{R2}}{R2} \times 100\% = \frac{1.9966}{130.79} \times 100\% = \underline{1.53\%}$$

## C.2 PRESSURE RATIO (P2) UNCERTAINTY

Since Q1 is the average of five pressures (Ports 6 - 10, see Appendix B),

$$U_{Q1} = .2[5(U_{\text{each channel}})^2]^{1/2} = .2\sqrt{5}(.04)$$

$$= .0179 \text{ in Hg}$$

$$Q2 = \frac{Q1}{29.92}$$

Therefore,

$$\frac{U_{Q2}}{Q2} = \frac{U_{Q1}}{Q1} = \frac{.0179}{59.622} = .0003$$

Similarly,

$$T3 = \left(\frac{T2}{518.7}\right)^{1/2}$$

$$\frac{U_{T3}}{T3} = \frac{1}{2}\frac{U_{T2}}{T2} = \frac{1}{2}\frac{.5}{636.40\ R} = .00039$$

$$W0 = \frac{\dot{W}_{ref}\quad Q2}{T3}$$

$$\frac{U_{W0}}{W0} = \left[\left(\frac{U_{\dot{W}_{ref}}}{\dot{W}_{ref}}\right)^2 + \left(\frac{U_{Q2}}{Q2}\right)^2 + \left(-\frac{U_{T3}}{T3}\right)^2\right]^{1/2}$$

From this point on, $\dot{W}_{ref}$ (referred flow rate) is assumed to be constant at 1.02 lbm/sec. Hence

$$\frac{U_{W0}}{W0} = [(-.00039)^2 + (.0003)^2]^{1/2} = .00049$$

and

$$\frac{U_{W4}}{W4} = \frac{U_{W0}}{W0} = .00049.$$

Continuing,

$$V1 = 109.62 \times SQR(T2)$$

$$\frac{U_{V1}}{V1} = \frac{1}{2}\frac{U_{T2}}{T2} = .00039$$

$$\frac{U_{V7}}{V7} = \left[\left(\frac{U_{W4}}{W4}\right)^2 + \left(\frac{U_{V1}}{V1}\right)^2 + \left(-\frac{U_{Q1}}{Q1}\right)^2\right]^{1/2}$$

$$\frac{U_{V7}}{V7} = [(.00049)^2 + (.00039)^2 + (-.0003)^2]^{1/2}$$

$$= .0007$$

$$V0 = \frac{M6}{W4 \times 4.18375}$$

$$\frac{U_{V0}}{V0} = [(\frac{U_{M6}}{M6})^2 + (- \frac{U_{W4}}{W4})^2]^{1/2}$$

$$= [(\frac{.99}{361.02})^2 + (-.00049)^2]^{1/2}$$

$$= .0027864$$

$$X0 = \frac{V0}{V1}$$

$$\frac{U_{X0}}{X0} = [(\frac{U_{V0}}{V0})^2 + (- \frac{U_{V1}}{V1})^2]^{1/2}$$

$$= [(.0027864)^2 + (-.00039)^2]^{1/2}$$

$$= .00281$$

$$Z0 = \frac{0.402}{2.402}[(V7)^2 \times (1 - (X0)^2) - .018(\frac{R2}{Q1})^2]$$

Let

$$L = 1 - (X0)^2.$$

Since $X0 = .5435$ (using data for this point),

$$\frac{U_L}{L} = \frac{2(X0)^2}{1 - (X0)^2} \times \frac{U_{X0}}{X0} = \frac{2(.5435)^2}{1 - (.5435)^2}(.00281) = .00236$$

Let $A = (V7)^2 L$, then

$$\frac{U_A}{A} = [(2\frac{U_{V7}}{V7})^2 + (\frac{U_L}{L})^2]^{1/2}$$

$$= [(2 \times .0007)^2 + (.00236)^2]^{1/2}$$

$$= .00274$$

Let $B = .018(\frac{R2}{Q1})^2$. Then,

$$\frac{U_B}{B} = 2[[\frac{U_{R2}}{R2}]^2 + [-\frac{U_{Q1}}{Q1}]^2]^{1/2}$$

$$= 2[(.0153)^2 + (-.0003)^2]^{1/2}$$

$$= .0305$$

Therefore,

$$Z0 = .167(A - B)$$

$$\frac{U_{Z0}}{Z0} = [(\frac{.167A}{A - B}\ \frac{U_A}{A})^2 + (-\frac{.167B}{A - B}\ \frac{U_B}{B})^2]^{1/2}$$

From the definitions of A and B,

$$A = (V7)^2 L \qquad \text{and} \qquad B = .018(\frac{R2}{Q1})^2$$

For this point,

$$V7 = .3571$$

$$L = 1 - (X0)^2 = .7045$$

$$R2 = 130.79$$

$$Q1 = 59.622$$

Hence,

$$A = (.3571)^2(.7045) = .0898$$

$$B = .018\left(\frac{130.79}{59.622}\right)^2 = .0865$$

$$\frac{U_{Z0}}{Z0} = \left[\left(\frac{.167(.0898)}{.0898 - .0865} \times .00274\right)^2 + \left(\frac{-.167(.0865)}{.0898 - .0865}\right) \times .0305)^2\right]^{1/2}$$

$$= .1353$$

Note here again, the predominant effect is from R2 in the uncertainty error of Z0. Continuing,

$$B0 = .0558 \frac{R2}{Q1}$$

$$\frac{U_{B0}}{B0} = \left[\left(\frac{U_{R2}}{R2}\right)^2 + \left(- \frac{U_{Q1}}{Q1}\right)^2\right]^{1/2}$$

$$= [(.0153)^2 + (.0003)^2]^{1/2} = .0153$$

Now

$$P2 = B0 + SQR((B0)^2 - Z0)$$

Let $C = (B0)^2 - Z0$, then

$$\frac{U_C}{C} = [(\frac{2(B0)^2}{(B0)^2 - Z0} \frac{U_{B0}}{B0})^2 + (- \frac{Z0}{(B0)^2 - Z0} \frac{U_{Z0}}{Z0})^2]^{1/2}$$

For this point,

$$B0 = .1224$$

$$Z0 = 5.49267 \times 10^{-4}$$

therefore

$$\frac{U_C}{C} = [(\frac{2(.1224)^2}{(.1224)^2 - (5.49 \times 10^{-4})}(.0153))^2$$

$$+ (- \frac{5.49267 \times 10^{-4}}{(.1224)^2 - (5.49 \times 10^{-4})}(.1353))^2]^{1/2}$$

$$= .0321$$

Note here the predominant effect of the B0 term which in turn is due almost exclusively to the P2 terms. Continuing,

$$P2 = B0 + \sqrt{C}$$

$$\frac{U_{P2}}{P2} = [(\frac{B0}{B0 + SQR(C)} \frac{U_{B0}}{B0})^2 + (\frac{\frac{1}{2} C^{1/2}}{B0 + SQR(C)} \frac{U_C}{C})^2]^{1/2}$$

Here,

$$C = (.1224)^2 - (5.49 \times 10^{-4}) = .01445$$

$$\sqrt{C} = .202.$$

Therefore,

$$\frac{U_{P2}}{P2} = [(\frac{.1224}{(.1224) + .1202}(.0153))^2 + (\frac{\frac{1}{2}(.1202)}{.1224 + .1202}(.0321))^2]^{1/2}$$

$$= .0111$$

*Note the almost total influence of R2 over the uncertainty in P2.*

### C3. STATOR LOSS COEFFICIENT ($\zeta_S$) UNCERTAINTY

The calculation of the uncertainty in stator loss coefficient requires first the calculation of the uncertainties in the intermediate variables defined in the data reduction program. In the calculation of the axial component of the velocity,

$$X1' = 3.487562189 \frac{P2}{V7}$$

$$\frac{U_{X1'}}{X1'} = [(\frac{U_{P2}}{P2})^2 + (-\frac{U_{V7}}{V7})^2]^{1/2}$$

$$= [(.0111)^2 + (-.0007)^2] = .0111$$

Then

$$X1 = - X1' + SQR((X1')^2 - (X0)^2 + 1)$$

Let $D = (X1')^2 - (X0)^2 + 1$. Then,

$$\frac{U_D}{D} = [(\frac{2(X1')^2}{(X1')^2 - (X0)^2 + 1}(\frac{U_{X1'}}{X1'}))^2 + (\frac{2(X0)^2}{(X1')^2 - (X0)^2 + 1}(\frac{U_{X0}}{X0}))^2]^{1/2}$$

For this point

$$X1' = 3.487(\frac{.2427}{.3571}) = 2.37$$

$$X0 = .5436$$

Therefore,

$$\frac{U_D}{D} = [(\frac{2(2.37)^2}{(2.37)^2 - (.5436)^2 + 1}(.0111))^2$$

$$+ (-\frac{2(.5436)^2}{(2.37)^2 - (.5436)^2 + 1}(.00281))^2]^{1/2}$$

$$= .01972$$

The predominant effect here is from P2 and therefore from R2.

Since X1 = SQR(D) - X1',

$$\frac{U_{X1}}{X1} = [(\frac{\frac{1}{2}D^{1/2}}{D^{1/2} - X1'}\frac{U_D}{D})^2 + (-\frac{X1'}{D^{1/2} - X1'}\frac{U_{X1'}}{X1'})^2]^{1/2}$$

For this point,

$$D = (2.37)^2 - (.5436)^2 + 1 = 6.323$$

so that

$$\frac{U_{X1}}{X1} = [(\frac{\frac{1}{2}(6.323)^{1/2}}{(6.323)^{1/2} - (2.37)}(.01972))^2$$

$$+ (-\frac{2.37}{(6.323)^{1/2} - (2.37)}(.0111))^2]^{1/2}$$

$$= .2506$$

Again, the prime contributors to the uncertainty in the axial component of velocity is due to P2, and therefore to R2. Note also the high errors introduced through taking differences between calculated quantities as in the denominators of the bracketed terms in the X1 uncertainty formula. Continuing,

$$X2 = SQR((X0)^2 + (X1)^2)$$

Let

$$E = (X0)^2 + (X1)^2 \rightarrow \frac{U_E}{E} = [(\frac{2(X0)^2}{(X0)^2 + (X1)^2}\frac{U_{X0}}{X0})^2$$

$$+ (\frac{2(X1)^2}{(X0)^2 + (X1)^2}\frac{U_{X1}}{X1})^2]^{1/2}$$

For this point,

$$X1 = .144224719$$

Therefore,

$$\frac{U_E}{E} = [(\frac{2(.5436)^2}{(.5436)^2 + (.1442)^2}(.00281))^2$$

$$+ (\frac{2(.1442)^2}{(.5436)^2 + (.1442)^2}(.2506))^2]^{1/2}$$

$$= .03338$$

$$X2 = SQR\ E$$

$$\frac{U_{X2}}{X2} = \frac{1}{2}\frac{U_E}{E} = .0167$$

The predominant effect is from X1, and therefore again from R2 through its effect on P2. Finally,

$$Z1 = \zeta_S = 1 - \frac{(X2)^2}{1 - (P2)^{.287}}$$

Let

$$G = 1 - P2^{.287}$$

Then

$$\frac{U_G}{G} = [(- \frac{.287(P2)^{.287}}{1 - (P2)^{.287}} \times \frac{U_{P2}}{P2})^2]^{1/2}$$

$$= [(- \frac{.287(.2427)^{.287}}{1 - (.2427)^{.287}} \times .0111)^2]^{1/2}$$

$$= .00634$$

Let $H = \frac{(X2)^2}{G}$. Then

$$\frac{U_H}{H} = [(2 \frac{U_{X2}}{X2})^2 + (- \frac{U_G}{G})^2]^{1/2}$$

$$= [(2 \times .0167)^2 + (-.00634)^2]^{1/2}$$

$$= .03398$$

*Note the predominant effect of the X2 term and, through X1 and P2, the overriding importance of the uncertainty in R2.* Continuing,

$$Z1 = 1 - H$$

$$\frac{U_{Z1}}{Z1} = [(- \frac{H}{1 - H} \frac{U_H}{H})^2]^{1/2}$$

$$H = \frac{(X2)^2}{G} = \frac{(X2)^2}{1 - (P2)^{.287}}$$

For this point

$$X2 = .562373442$$

Therefore,

$$H = \frac{(.562)^2}{1 - (.2427)^{.287}} = .9478$$

and

$$\frac{U_{Z1}}{Z1} = [(-\frac{.9478}{1 - .9478} \times .03398)^2]^{1/2}$$

$$= .617$$

*As can be seen, the uncertainty in the axial force (R2) is the major contributor to the uncertainty in the calculated interstage pressure and consequently to the stator loss coefficient*. The uncertainty in R2, however, is in turn determined primarily by the uncertainties in two key pressure measurements. The measurements corresponding to computer program parameters Q3 and R8 are those on ports 11 and 21 which are connected to the hood and to the closure plate volume.

## C.4. ROTOR LOSS COEFFICIENT ($\zeta_R$) UNCERTAINTY

The uncertainty in the rotor torque is obtained using the measurement uncertainty:

$$\frac{U_{M5}}{M5} = \frac{.427 \text{ in-lbf}}{446.90} = 0.000955$$

Then,

$$X4 = .984\ X0 - .235 \frac{M5}{W4(V1)}$$

Let

$$I = \frac{M5}{W4(V1)}$$

$$\frac{U_I}{I} = [(\frac{U_{M5}}{M5})^2 + (-\frac{U_{W4}}{W4})^2 + (-\frac{U_{V1}}{V1})^2]^{1/2}$$

$$= [(0.00095)^2 + (-.00049)^2 + (-.00039)^2]^{1/2}$$

$$= .00114$$

Therefore,

$$\frac{U_{X4}}{X4} = [(\frac{.984X0}{.984X0 - .235I}(\frac{U_{X0}}{X0}))^2 + (\frac{-.235I}{.984X0 - .235I}(\frac{U_I}{I}))^2]^{1/2}$$

$$I = \frac{M5}{W4(V1)} = \frac{446.9}{(.0574)(2765.36)} = 2.815$$

Let

$$J = U3(X0) - U4(X4)$$

and

$$K = U3(X0)$$

$$L = U4(X4)$$

$$\frac{U_K}{K} = [(\frac{U_{U3}}{U3})^2 + (\frac{U_{X0}}{X0})^2]^{1/2}$$

$$= [(.0158)^2 + (.00281)^2]^{1/2} = .0161$$

$$\frac{U_L}{L} = [(\frac{U_{U4}}{U4})^2 + (\frac{U_{X4}}{X4})^2]^{1/2}$$

$$= [(.0158)^2 + (.00696)^2]^{1/2} = .0172$$

Therefore,

$$J = K - L$$

giving

$$\frac{U_J}{J} = [(\frac{K}{K-L}\frac{U_K}{K})^2 + (\frac{-L}{K-L}\frac{U_L}{L})^2]^{1/2}$$

$$K = \frac{U3(X0)}{V1} = \frac{.0365(11077)(.5435)}{2765.362559} = .07949$$

$$L = U4(X4) = \frac{.0371(11077)(-.1272)}{2765} = -.0189$$

$$X4 = .984(.5536) - .235(2.815) = -.1272$$

$$\frac{U_J}{J} = [(\frac{.07949}{.07949 - (-.0189)}(.0161))^2 + (\frac{-(-.0189)}{.07949 - (-.0189)}(.0172))^2]^{1/2}$$

$$= .01338$$

Let

$$M = 1 - (X4)^2 = 1 - (-.1272)^2 = .9838$$

therefore,

$$\frac{U_M}{M} = \frac{2(X4)^2}{1-(X4)^2}\frac{U_{X4}}{X4} = \frac{2(-.1272)^2}{1-(-.1272)^2}(.00696)$$

$$= .000229$$

$$Z2 = M - 2(J)$$

$$J = K - L = .07949 - (-.0189) = .0984$$

$$\frac{U_{Z2}}{Z2} = [(\frac{M}{M-2J}\ \frac{U}{\ })^2 + (\frac{-2J}{M-2J}\ \frac{U_J}{J})^2]^{1/2}$$

$$= [(\frac{.9838}{.9838 - 2(.0984)}(.000229))^2$$

$$+ (\frac{-2(.0984)}{.9838 - 2(.0984)}(.01338))^2]^{1/2}$$

$$= .00336$$

$$\frac{U_{X4}}{X4} = [\frac{.984(.5435)}{.984(.5435) - .235(2.815)}(.00281))^2$$

$$+ (\frac{-.235(2.815)}{.984(.5435) - .235(2.815)}(.00114))^2]^{1/2}$$

$$= .00696$$

$$Z2 = (1 - (X4)^2) - 2(U3)(X0) - (U4)(X4)$$

$$U3 = \frac{U1}{V1}$$

$$U1 = .0365(N)$$

$$\frac{U_{U1}}{U1} = \frac{U_N}{N} = \frac{175}{11077} = .01579$$

Therefore,

$$\frac{U_{U3}}{U3} = [(\frac{U_{U1}}{U1})^2 + (-\frac{U_{V1}}{V1})^2]^{1/2} = [(.01579)^2 + (-.00039)^2]^{1/2}$$

$$= .0158$$

Now,

$$U4 = \frac{U2}{V1},$$

where

$$U2 = .0371(N)$$

Therefore,

$$\frac{U_{U2}}{U2} = \frac{U_{U1}}{U1} = .01579$$

and

$$\frac{U_{U4}}{U4} = \frac{U_{U3}}{U3} = .0158$$

$$P9 = \frac{S9 + Q3}{2}$$

$$\frac{U_{P9}}{P9} = [(\frac{0.5(S9)}{S9 + Q3} \frac{U_{S9}}{S9})^2 + ((\frac{0.5 Q3}{S9 + Q3}) \frac{U_{Q3}}{Q3})^2]^{1/2}$$

$$= [(\frac{0.5(.04)}{34.2929})^2 + (\frac{0.5(.04)}{34.2929})^2]^{1/2}$$

$$= .0008247$$

$$S9 = 17.0582$$

$$\frac{U_{S9}}{S9} = \frac{.04}{17.0582} = .00234$$

$$Q3 = 17.2347$$

$$\frac{U_{Q3}}{Q3} = \frac{.04}{17.2347} = .00232$$

$$B1 = 38.78\left(\frac{P9}{W4\,(V1)}\right)$$

and

$$P9 = 17.14645$$

therefore,

$$\frac{U_{B1}}{B1} = \left[\left(\frac{U_{P9}}{P9}\right)^2 + \left(-\frac{U_{W4}}{W4}\right)^2 + \left(-\frac{U_{V1}}{V1}\right)^2\right]^{1/2}$$

$$= [(.0008247)^2 + (-.00049)^2 + (-.00039)^2]^{1/2}$$

$$= .0010356$$

$$X5 = -B1 + SQR((B1)^2 + Z2)$$

Let

$$N = (B1)^2 + Z2$$

and since

$$B1 = 4.188649456$$

$$Z2 = .78699067$$

$$\frac{U_N}{N} = [(\frac{2(B1)^2}{(B1)^2 + Z2} \frac{U_{B1}}{B1})^2 + (\frac{Z2}{(B1)^2 + Z2} \frac{U_{Z2}}{Z2})^2]^{1/2}$$

$$= [(\frac{2(4.188)^2}{(4.188)^2 + (.78699)} (.0010356))^2$$

$$+ (\frac{.78699}{(4.188)^2 + (.78699)} (.00336))^2]^{1/2}$$

$$= .00198$$

Therefore,

$$X5 = -B1 + \sqrt{N}$$

and

$$N = 18.33177494$$

$$\frac{U_{X5}}{X5} = [(\frac{0.5\ SQR(N)}{-B1 + SQR(N)} \frac{U_N}{N})^2 + (\frac{-B1}{-B1 + SQR(N)} \frac{U_{B1}}{B1})^2]^{1/2}$$

$$= [(\frac{0.5(18.33)^{1/2}}{-4.188 + (18.33)^{1/2}} (.00198))^2$$

$$+ (\frac{-4.188}{-4.188 + (18.33)^{1/2}} (.00104))^2]^{1/2}$$

$$= .0653122238$$

*Note that it is the differences in the denominators of each of the terms in the above equation which give rise to the large resultant uncertainty.* Continuing,

$$L0 = (X5)^2 + (X4 - U4)^2$$

Let

$$O = X4 - U4$$

Here,

$$U4 = .14856054$$

Therefore,

$$\frac{U_O}{O} = [(\frac{X4}{X4 - U4}\frac{U_{X4}}{X4})^2 + (\frac{-U4}{X4 - U4}\frac{U_{U_4}}{U4})^2]^{1/2}$$

$$= [(\frac{-.1273}{-.1273 - .1486}(.00696))^2$$

$$+ (\frac{-.1486}{-.1273 - .1486}(.0158))^2]^{1/2}$$

$$= .009096$$

$$L0 = (X5)^2 + (O)^2$$

and here

$$X5 = .092912751$$

$$O = -.2758526482$$

Therefore,

$$\frac{U_{L0}}{L0} = [(\frac{2(X5)^2}{(X5)^2 + (O)^2} \frac{U_{X5}}{X5})^2 + (\frac{2(O)^2}{(X5)^2 + (O)^2} \frac{U_O}{O})^2]^{1/2}$$

$$= [(\frac{2(.0929)^2}{(.0929)^2 + (-.2759)^2}(.0653))^2$$

$$+ (\frac{2(-.2759)^2}{(.0929)^2 + (-.2759)^2}(.00909))^2]^{1/2}$$

$$= .021073843$$

$$L1 = (1 - (X2)^2)\ (1 - (\frac{P9}{(P2*Q1)})^{G0})$$

$$+ (X2)^2 - 2X0(U3) + (U4)^2$$

Let

$$P = 1 - (X2)^2$$

$$\frac{U_P}{P} = \frac{2(X2)^2}{1 - (X2)^2} \frac{U_{X2}}{X2} = \frac{2(.562373442)^2}{1 - (.562373442)^2}(.0167)$$

$$= .0154492555$$

Let

$$Q = \frac{P9}{P2(Q1)}$$

$$\frac{U_Q}{Q} = [(\frac{U_{P9}}{P9})^2 + (\frac{U_{P2}}{P2})^2 + (\frac{U_{Q1}}{Q1})^2]^{1/2}$$

$$= [(.00082)^2 + (.0111)^2 + (.0003)^2]^{1/2}$$

$$= .0111$$

Note that the P2 term predominates here again. Let

$$R = 1 - Q^{G0}$$

$$Q = \frac{P9}{P2(Q1)} = \frac{17.14645}{(.242704755)(59.62218)}$$

$$= 1.1849$$

$$\frac{U_R}{R} = \frac{G0(Q)^{G0}}{1 - Q^{G0}} \frac{U_Q}{Q} = \frac{.2867(1.1849)^{.2867}}{1 - (1.1849)^{.2867}}(.0111)$$

$$= .0670486725$$

Let

$$S = P \times R$$

Then

$$\frac{U_S}{S} = [(\frac{U_P}{P})^2 + (\frac{U_R}{R})^2]^{1/2}$$

$$= [(.0154)^2 + (.067048)^2]^{1/2}$$

$$= .0688$$

Let

$$T = (X2)^2$$

$$\frac{U_T}{T} = 2 \frac{U_{X2}}{X2} = 2(.0167) = .03339$$

Let

$$V = 2X0(U3)$$

$$\frac{U_V}{V} = [(\frac{U_{X0}}{X0})^2 + (\frac{U_{U3}}{U3})^2]^{1/2}$$

$$= [(.00281)^2 + (.0158)^2]^{1/2}$$

$$= .01605$$

Let

$$W = (U4)^2$$

$$\frac{U_W}{W} = 2\frac{U_{U4}}{U4} = 2(.0158) = .0316$$

$$L1 = S + T - V + W$$

$$S = P \times R = (1 - (X2)^2)(1 - (Q)^{G0}$$

$$= (1 - (.56237373442)^2)(1 - (1.1849)^{.2867})$$

$$= -.034$$

$$T = (X2)^2 = .316$$

$$V = 2(X0)(U3) = 2(.543565192)(.146240442)$$

$$= .15898$$

$$W = (U4)^2 = (.1485)^2 = .02207$$

Therefore,

$$L1 = .1452648551$$

$$\frac{U_{L1}}{L1} = [(\frac{S}{L1}\frac{U_S}{S})^2 + (\frac{T}{L1}\frac{U_T}{T})^2 + (\frac{-V}{L1}\frac{U_V}{V})^2 + (\frac{W}{L1}\frac{U_W}{W})^2]^{1/2}$$

$$= [(\frac{-.034}{.1453}(.0688))^2 + (\frac{.316}{.1453}(.03339))^2$$

$$+ (\frac{-.15898}{.1453}(.01605))^2 + (\frac{.02207}{.1453}(.0316))^2]^{1/2}$$

$$= .07664$$

The largest effect here is from T, by an order of magnitude. The uncertainty in T alone would have given $\frac{U_{L1}}{L1} = 0.0726$. Therefore $X2 = \sqrt{T}$ is the most important term.

Finally,

$$Z3 = \zeta_R = 1 - \frac{L0}{L1}$$

Let

$$X = \frac{L0}{L1}$$

Then

$$\frac{U_X}{X} = [(\frac{U_{L0}}{L0})^2 + (-\frac{U_{L1}}{L1})^2]^{1/2}$$

$$= [(.021)^2 + (-.07664)^2]^{1/2} = .07948$$

Here, the effect of the L1 term is overwhelming, which again points to the term X2, and consequently to P2, and R2. Finally,

$$Z3 = \zeta_R = 1 - X$$

where

$$X = \frac{L0}{L1} = \frac{.084729915}{.145264855} = .5832788323$$

Therefore,

$$\frac{U_{Z3}}{Z3} = \frac{X}{1 - X}\frac{U_X}{X} = (\frac{.5833}{1 - .5832})(.07948)$$

$$= \underline{.11125}$$

## C.5 SIMPLIFIED ANALYSIS

Given the predominance of the R2 term in both loss coefficient calculations, we can simplify the uncertainty calculation at any point by dropping all uncertainty terms which have a magnitude which is less than one fifth of the R2 uncertainty. With this approximation,

$$U_{R2} = 1.9966 \text{ lbf} \quad \text{(exact for all values of R2)}$$

or

$$\frac{U_{R2}}{R2} = \frac{1.9966}{R2} \quad \text{for a given R,}$$

and the uncertaintiies in Q1, Q2, T3, W0, W4, V1, V7, V0 and X0 will be considered to be negligible. Under the same approximation,

$$\frac{U_{B0}}{B0} = \frac{U_{R2}}{R2}$$

and

$$\frac{U_C}{C} = \frac{2(B0)^2}{(B0)^2 - Z0} \frac{U_{R2}}{R2}$$

where

$$C = (B0)^2 - Z0$$

and finally

$$\frac{U_{P2}}{P2} = [(\frac{B0}{B0 + SQR(C)} \frac{U_{B0}}{B0})^2 + (\frac{0.5C^{1/2}}{B0 + SQR(C)} \frac{U_C}{C})^2]^{1/2}$$

where again B0 and Z0 must be obtained from the computer reduction for a given point. Then

$$\frac{U_{X1'}}{X1'} = \frac{U_{P2}}{P2}$$

$$\frac{U_D}{D} = (\frac{2(X1')^2}{(X1')^2 - (X0)^2 + 1} \frac{U_{X1'}}{X1'})$$

$$= \frac{2(X1')^2}{(X1')^2 - (X0)^2 + 1} \frac{U_{P2}}{P2}$$

where

$$D = (X1')^2 - (X0)^2 + 1$$

$$X1' = 3.487562189 \frac{P2}{V7}$$

and X0, P2 must be again determined from program reduction.

Now

$$\frac{U_{X1}}{X1} = [(\frac{0.5D^{1/2}}{D^{1/2} - X1'} \frac{U_D}{D})^2 + (-\frac{X1'}{D^{1/2} - X1'} \frac{U_{X1'}}{X1'})^2]^{1/2}$$

and

$$\frac{U_{X2}}{X2} = \frac{1}{2}[(\frac{2(X1)^2}{(X0)^2 + (X1)^2} \frac{U_{X1}}{X1})^2]^{1/2}$$

$$= \frac{(X1)^2}{(X0)^2 + (X1)^2} \frac{U_{X1}}{X1}$$

and

$$\frac{U_H}{H} = 2 \frac{U_{X2}}{X2}$$

where

$$H = \frac{(X2)^2}{1 - P2^{0.287}}$$

so that

$$\frac{U_{Z1}}{Z1} = \frac{U_{\zeta_S}}{\zeta_S} = \frac{H}{1 - H}(\frac{U_H}{H}).$$

In summary, to calculate the uncertainty in $\zeta_S$ at a given point the following parameters must be obtained: R2, Q1, V7, X0, B0, Z0, P2; and X1'. Note: X1' must be calculated as its value is not retained in the current reduction program.

Similarly for the rotor loss coefficient ($\zeta_R$), the prime effect is also through the R2 term. We can obtain a satisfactory approximation by dropping all contributions to the L1 term except X2. This gives

$$\frac{U_{L1}}{L1} = \frac{(X2)^2}{L1} \frac{U_T}{T} = \frac{(X2)^2}{L1}(2) \frac{U_{X2}}{X2}$$

Therefore,

$$\frac{U_X}{X} = \frac{U_{L1}}{L1}$$

and

$$\frac{U_{Z3}}{Z3} = \frac{U_{\zeta_S}}{\zeta_S} = \frac{X}{1 - X} \frac{U_X}{X}$$

where

$$X = \frac{L0}{L1}$$

Using these approximations for calculating the $\zeta_S$ and $\zeta_R$ we obtain for the sample point

$$\frac{U_{Z1}}{Z1} = .593 \qquad \text{and} \qquad \frac{U_{Z3}}{Z3} = .0996.$$

Comparison shows that for $\zeta_S$ this is only 3% below the exact uncertainty and for $\zeta_R$ only 10% below the exact uncertainty. The above approximate formulas have been incorporated into a computer program and used to calculate the uncertainty in R2, P2, Z1, and Z3 for all points in runs 10-15. The program is

called "UNCERT" and is listed as part of Appendix A. A summary of the approximate formulas and required inputs is listed in Table C-IV.

## Table C-I

## DEFINITION OF TERMS

A8 - Partial integral of rotor shroud pressure over area

A9 - Partial integral of rotor shroud pressure over area

B0 - Equation (8) from Ref. 7

B1 - Equation (16) from Ref. 7

B2 - Beta 1 ($\beta_1$) - relative flow angle

B5 - Partial integral of rotor shroud pressure over area

B6 - Partial integral of rotor shroud pressure over area

B7 - Partial integral of rotor shroud pressure over area

F0' - Total axial force-stator

F0 - Partial integral of rotor shroud pressure over area

F1 - Partial integral of rotor shroud pressure over area

F2 - Closure Plate force

F3 - Stator exit force

F4 - Stator axial force - force capsule

F5 - Closure plate force - force capsule

G0 - Ratio of $(\gamma-1)/\gamma = .2857$

L0 - Intermediate product in rotor loss coefficient calculation

L1 - Intermediate product in rotor loss coefficient calculation

M5 - Rotor torque

M6 - Stator torque

N - Rotor RPM

N0 - Rotor shroud static pressure

## TABLE C-I (Cont'd)

N1 - Rotor shroud static pressure

N2 - Rotor shroud static pressure

N3 - Rotor shroud static pressure

N4 - Rotor shroud static pressure

N5 - Rotor shroud static pressure

N6 - Rotor shroud static pressure

N7 - Rotor shroud static pressure

N8 - Rotor shroud static pressure

N9 - Rotor shroud static pressure

O1 - Rotor shroud static pressure

P1 - Ratio of hood pressure to labrinth pressure

P2 - Ratio $P_1/P_{t_o}$

P9 - Average rotor exit pressure

Q1 - P

Q2 - Ratio of $P_{t_o}/P_{ref}$

Q3 - Hood pressure

Q4 - Static pressure at stator tap "tip #3"

R2 - Resultant force on stator

R8 - Static pressure at stator tap "hub #3"

S3 - Rotor shroud static pressure

S4 - Rotor shroud static pressure

S5 - Rotor shroud static pressure

S6 - Rotor shroud static pressure

S7 - Rotor shroud static pressure

S8 - Rotor shroud static pressure

S9 - Rotor shroud static pressure

## TABLE C-I (Cont'd)

T2 - $T_{t_o}$

T3 - $\sqrt{\theta}$

U1 - Intermediate calculation

U2 - Intermediate calculation

U3 - Dimensionless rotor velocity

U4 - Dimensionless rotor velocity

V0 - Rotor tangential velocity ($V_{U1}$)

V1 - Limiting velocity ($V_{t_o}$)

V7 - Ratio $\overline{P}_1/P_{t_o}$

W0 - Total mass flow rate

W4 - Ratio W0/g = W0/32.174

X0 - Dimensionless velocity ($X_{U1}$)

X1' - Intermediate calculation for obtaining X1

X1 - Dimensionless velocity ($X_{a1}$)

X2 - Dimensionless velocity ($X_1$)

X4 - Dimensionless velocity ($X_{U2}$)

X5 - Dimensionless velocity ($X_{a2}$)

X7 - Blockage factor = 1

X8 - Intermediate calculation $(\gamma(2(X7) - 1) + 1) = 2.402$

Z0 - Intermediate calculation for stator exit pressure

Z1 - Stator loss coefficient - $\zeta_S$

Z2 - Intermediate calculation for $X_{a2}$

Z3 - Rotor loss Coefficient - $\zeta_R$

Greek letters

$\beta$ - relative flow angle (degrees)

$\gamma$ - ratio of specific heats

## TABLE C-I (Cont'd)

$\zeta$ - loss coefficient

$\theta$ - ratio of total inlet temperature to standard atmospheric temperature (518.7°R)

### Subscripts

a - axial direction

ref - referred quantity

R - rotor

S - stator

t (or $t_o$) - total condition

u - peripheral component

0 - stator entrance

1 - stator exit

2 - rotor discharge

## Table C-II

## UNCERTAINTIES ASSIGNED TO RAW DATA PARAMETERS

| | | |
|---|---|---|
| Temperature | | ± 0.5°F |
| Pressure | | ± 0.04 in Hg |
| | or | ± 0.54 in $H_2O$ |
| Stator Torque | | ± 0.99 in-lbf |
| Rotor Torque | | ± 0.427 in-lbf |
| Force Capsules | | ± 0.48 lbf |
| RPM | | ± 175 RPM |

## Table C-III

## RAW DATA FOR RUN 10 POINT 1

$X0 = 0.5435$

$X1 = 0.1442$

$X2 = 0.5624$

$V7 = 0.3571$

$B0 = 0.1224$

$Z0 = 5.49267 \times 10^{-4}$

$B1 = 4.1886$

$Z2 = 0.7870$

$X5 = .0929$

$P9 = 17.14645$ in Hg

$P2 = 0.2427$

$R2 = 130.79$ lbf

$T2 = 636.4$ °R

$Q1 = 59.622$ in Hg

$M5 = 446.90$ in-lbf

$M6 = 361.02$ in-lbf

$F4 = -121.87$ lbf

$F5 = 5.90$ lbf

$N = 11077$ RPM

Table C-IV

## UNCERTAINTY APPROXIMATION FORMULAS

| Parameter | Formulas | Inputs |
|---|---|---|
| R2 | $\frac{U_{R2}}{R2} = \frac{1.9966}{R2}$ | R2 |
| P2 | $\frac{U_{C}}{C} = \frac{2(B0)^2}{(B0)^2 - Z0} \frac{U_{R2}}{R2}$ | B0, Z0, $\frac{U_{R2}}{R2}$ |
|  | where $C = (B0)^2 - Z0$ | B0, Z0 |
|  | $\frac{U_{P2}}{P2} = [(\frac{B0}{B0 + SQR(C)} \frac{U_{R2}}{R2})^2 + (\frac{0.5C^{1/2}}{B0 + SQR(C)} \frac{U_{C}}{C})^2]^{1/2}$ | B0, Z0, C, $\frac{U_{R2}}{R2}$, $\frac{U_{C}}{C}$ |
| Z1 | $\frac{U_{D}}{D} = \frac{2(X1')^2}{D} \frac{U_{P2}}{P2}$ | X1', D, $\frac{U_{P2}}{P2}$ |
|  | where $D = (X1')^2 - (X0)^2 + 1$ | X1', X0 |
|  | $\frac{U_{X1}}{X1} = [(\frac{0.5D^{1/2}}{D^{1/2} - X1'} \frac{U_{D}}{D})^2 + (-\frac{X1'}{D^{1/2} - X1'} \frac{U_{P2}}{P2})^2]^{1/2}$ | D, X1', $\frac{U_{D}}{D}$, $\frac{U_{P2}}{P2}$ |
|  | $\frac{U_{X2}}{X2} = \frac{(X1)^2}{(X0)^2 + (X1)^2} \frac{U_{X1}}{X1}$ | X0, X1, $\frac{U_{X1}}{X1}$ |

| | | |
|---|---|---|
| | $\frac{U_H}{H} = 2 \frac{U_{X2}}{X2}$ | $U_{X2}$, X2 |
| | where $H = \frac{(X2)^2}{1 - (P2)^{G0}}$ | X2, P2 |
| | $\frac{U_{Z1}}{Z1} = \frac{H}{1 - H} \frac{U_H}{H}$ | H, $\frac{U_H}{H}$ |
| Z3 | $\frac{U_{L1}}{L1} = 2 \frac{(X2)^2}{L1} \frac{U_{X2}}{X2}$ | X2, L1, $\frac{U_{X2}}{X2}$ |
| | $\frac{U_{Z3}}{Z3} = \frac{X}{1 - X} \frac{U_{L1}}{L1}$ | X, $\frac{U_{L1}}{L1}$ |
| | where $X = \frac{L0}{L1}$ | L0, L1 |

# APPENDIX D

## CALCULATION OF CONDENSATION EFFECTS IN THE STATOR NOZZLES

### D.1 SUPERCOOLING IF CONDENSATION IS ABSENT

The present calculations follow the methods given in Cahpter 10 of Reference 13. The symbols used (in this section only) are as follows:

$P_{t_o}$ = total pressure

$T_{t_o}$ = total temperature

$P$ = static pressure

$T$ = static temperature

$T_{DP}$ = dew point temperature

$P_g$ = saturation pressure of the water vapor at the mixture temperature

$P_w$ = partial pressure of the water vapor

$P_a$ = partial pressure of the dry air

$P$ = total pressure of the mixture = $P_a + P_w$

$\phi$ = relative humidity = $\frac{P_w}{P_g}$

$\gamma$ = specific humidity = $0.622 \frac{P_w}{P_a}$

$m$ = mach number

$\Delta T$ = $T - T_{DP}$

Subscripts

1 = compression intake

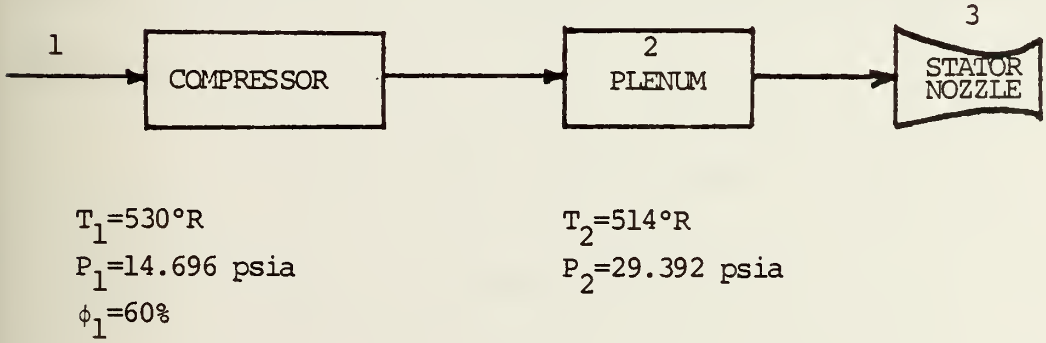
2 = turbine plenum

3 = stator nozzle

The purpose of the calculations which follow is to examine the static temperature variation in the flow through the stator nozzles and to assess the likelihood that condensation will occur. The calculations are carried out for the air-water vapor mixture entering the Allis-Chalmers compressor at typical Monterey weather conditions. The question is - does the normal air flow through the stator nozzle supercool sufficiently to produce condensation within the nozzle itself? The recorded weather data for Monterey for the days of the tests in this report showed a limited variation in relative humidity and temperature of $\phi = 60 - 70\%$ and $T = 60 - 70$ °F respectively. Therefore, the following conditions were assumed:

$$\phi = 60\% \qquad T = 70\ °F$$

The process to be analyzed is shown schematically in the following sketch:



The calculations are for the worst case, say run 12 or 13, where the lowest supply temperature ($T_{t_o}$ = 574 °R) would give rise to the greatest degree of supercooling.

The calculation is carried out as follows: First the pressure and temperature for a perfect gas isentropic expansion is calculated to an assumed Mach number. Then, assuming the flow remains saturated, but free of condensation the partial pressure of water vapor is calculated. From the known pressure and partial pressure the dew point temperature is obtained from tables. The degree of supersaturation is then the difference between the calculated gas temperature and the dew point temperature.

Since no water vapor is added in the compressor, the specific humidity of the air does not change from atmospheric inlet to stator nozzle conditions. At atmospheric inlet conditions,

$$\phi = 0.60 = \frac{P_w}{P_g}$$

where, at 70 °F, $P_g$ = .3632 psia (saturation tables for water). Since

$$P = 1 \text{ atm} = 14.696 \text{ psia} = P_w + P_a$$

$$P_{a_1} = 14.696 - P_{w_1}$$

and

$$P_{w_1} = 0.60\, P_g = 0.60(.3632 \text{ psia})$$

$$P_{w_1} = .21792 \text{ psia.}$$

Therefore

$$\gamma_1 = 0.622 \frac{P_{w_1}}{P_{a_1}} = 0.622 \frac{P_{w_1}}{14.696 - P_{w_1}}$$

$$= 0.622\left(\frac{.21792}{14.696 - .21792}\right)$$

$$= .00936 \frac{\text{lbm } H_2O}{\text{lbm air}} .$$

This fraction ($\gamma$) remains constant up to the point at which condensation occurs in the nozzle. Therefore, at station 2,

$$\phi_2 = \frac{\gamma P_{a_2}}{0.622 P_{g_2}}$$

where

$$P_{g_2} = 1.4436 \text{ at } T = 574 \text{ °R}$$

Since $\gamma_1 = \gamma_2$, then

$$0.622 \frac{P_{w_1}}{P_{a_1}} = 0.622 \frac{P_{w_2}}{P_{a_2}} ,$$

or

$$\frac{P_{w_1}}{P_{a_1}} = \frac{P_{w_2}}{P_{a_2}} = \frac{P_{w_2}}{P_2 - P_{w_2}}$$

Writing,

$$P_{w_2} = \frac{P_{w_1}}{P_{a_1}}(P_2 - P_{w_2})$$

$$P_{w_2}\left(1 + \frac{P_{w_1}}{P_{a_1}}\right) = \frac{P_2 \; P_{w_1}}{P_{a_1}}$$

$$P_{w_2} = \frac{P_2 \; P_{w_1}/P_{a_1}}{1 + \dfrac{P_{w_1}}{P_{a_1}}}$$

$$= \frac{29.392(.21792/(14.696 - .21792))}{1 + \dfrac{.21792}{14.616 - .21792}}$$

$$= .43584 \text{ psia}$$

Therefore the relative humidity at stagnation conditions is given by

$$\phi_2 = \frac{\gamma_2 \; P_{a_2}}{0.622 \; P_{g_2}} = \frac{.00936(29.392 - .43584)}{0.622(1.4436)}$$

$$= .3019$$

Now $\phi$ will increase in the flow through the nozzle from the plenum to the nozzle throat to the nozzle exit, since the static temperature in the flow progressively drops.

For the purpose of calculating supercooling in the higher mach number region of the expansion, from this point it will

be assumed that the flow is fully saturated, that is to say, $\phi = 1$. It will also be assumed that no condensation actually occurs, and therefore $\gamma = 0.00936$.

The dew points are calculated on the basis of the partial pressure, $p_{w_1}$. Therefore, at any station 3 in the nozzle, if $\phi = 1$,

$$\frac{P_{w_3}}{P_{g_3}} = 1.0$$

or

$$P_{w_3} = P_{g_3}$$

and

$$\frac{P_{w_1}}{P_{a_1}} = \frac{P_{w_2}}{P_{a_2}} = \frac{P_{w_3}}{P_{a_3}}$$

until condensation occurs. Therefore,

$$P_{w_3} = \frac{P_{w_2}}{P_{a_2}} P_{a_3} = \frac{P_{w_2}}{P_{a_2}}(P_3 - P_{w_3})$$

or

$$P_{w_3} = \frac{\frac{P_{w_2}}{P_{a_2}} P_3}{1 + \frac{P_{w_2}}{P_{a_2}}}$$

Since

$$\frac{P_{w_2}}{P_{a_2}} = \frac{.43584}{29.392 - .43584} = .015$$

$$P_{w_3} = \frac{.015\ P_3}{1 + .015} = .0148\ P_3$$

when $P_3$ is obtained from isentropic tables for the expansion, the dew point temperature is obtained using Table B1-b of Ref. 13.

The results of the calculations for 5 mach numbers (or nozzle statics) are listed in Table D-I.

Table D-I

CALCULATED SUPERCOOLING (ΔT) IF NO CONDENSATION OCCURS AT $T_{t_o} = 574$ °R ($P_{t_o} = 2$ atms, $\phi = 0.6$ at intake conditions $T = 530$ °R and $p = 1$ atms)

| Station | Mach | P | $T_{t_o}$ | T | $T_{DP}$ | ΔT |
|---|---|---|---|---|---|---|
| 1 (throat) | 1.0 | 15.527 | 574 | 478 | 517 | -39 |
| 2 | 1.2 | 12.121 | 574 | 446 | 510 | -64 |
| 3 | 1.3 | 10.608 | 574 | 429 | 507 | -78 |
| 4 (nozzle exit) | 1.4 | 9.236 | 574 | 412 | 503 | -91 |
| 5 | 1.5 | 8.006 | 574 | 396 | 499 | -103 |

[Sample calculation: since $P_{w_3} = .0148\ P_3$, at station 2, $P_{w_3} = .0148(12.121) = .1797$ psia. From Table B1-b of Ref. 13, $T_{DP} = 510$ °R.]

The results of similar calculations for identical conditions except $T_{t_o}$ = 670 °R, are given in Table D-II.

Table D-II

CALCULATED SUPERCOOLING OF (ΔT) IF NO CONDENSATION OCCURS AT $T_{t_o}$ = 670 °R

($P_{t_o}$ = 2 atms, $\phi$ = 0.6 at intake conditions
T = 530 °R and P = 1 atms)

| Station | Mach | P | $T_{t_o}$ | T | $T_{DP}$ | ΔT |
|---|---|---|---|---|---|---|
| 1 (throat) | 1.0 | 15.527 | 670 | 558 | 517 | +41 |
| 2 | 1.2 | 12.121 | 670 | 520 | 510 | +10 |
| 3 | 1.3 | 10.608 | 670 | 501 | 507 | - 6 |
| 4 | 1.4 | 9.236 | 670 | 481 | 503 | -22 |
| 5 | 1.5 | 8.006 | 670 | 462 | 499 | -37 |

Note that a negative delta T implies supercooling. The results for the lower temperature ($T_{t_o}$ = 574 °R) indicate that the flow is supercooled from the throat to the exit plane, with ΔT = -103 °F at m = 1.5. Although the stator nozzle is designed for a Mach number of 1.4, expansion of the flow to the interstage pressure conditions will result in a slightly higher Mach number approaching 1.5.

## D.2 EFFECT OF CONDENSATION ON PRESSURE

The effect of condensation on pressures which would occur in the nozzle expansion were calculated using the method given on P. 205 of Ref. 15. If the condensation process is treated

as one in which the heat of condensation, $h_{fg}$, is added in the expansion process and acts to increase the stagnation temperature, then the effect on the static pressure is given by

$$\frac{dP}{P} = - \frac{Km^2(1 + \frac{K-1}{2} M^2)}{(1 - M^2)} f(\frac{h_{fg}}{C_p T_{t_o}})$$

where K = ratio of specific heats and f = mass fraction which condenses. Using K = 1.4,

$$h_{fg} = 1000 \text{ Btu/lbm}, \quad C_p = .45 \text{ Btu/lbm-°R}$$

and

$$T_{t_o} = 574 \text{ °R} ,$$

and letting M = 1.2,

$$\frac{dP}{P} = - \frac{(1.4)(1.2)^2(1 + 0.2(1.2)^2)}{(1 - 1.2^2)} f(\frac{1000}{.446(574)})$$

$$= 23.05 \text{ f.}$$

Consequently for a 1% change in the pressure ratio to occur $(\frac{dP}{P} = 0.01)$,

$$f = 0.01/23.05 = .0004338 \frac{\text{lbm } H_2O}{\text{lbm air}} .$$

If this is the fraction of the total gas flow which is required to condense, then the fraction of the water present in the flow required to condense is given by

$$\frac{f}{\gamma} = \frac{.0004338}{.00936} = .046336.$$

Hence, 4.6% of the water in the flow would have to condense at M = 1.2 station to produce a 1% change in the pressure ratio.

# APPENDIX E

## RIG PROCEDURES

1. Prior to each run, observe and record the calibration of:

   a. stator axial force capsule
   b. stator torque capsule
   c. rotor torque capsule
   d. closure plate axial force capsule
   e. $\Delta P_{noz}$

2. Ensure aftercooler is drained so that a consistent high $T_{t_o}$ will be obtained for the run.

3. Observe and check calibration of the stator axial force capsule and $\Delta P_{noz}$ before and after each point to ensure consistency.

4. Avoid points in the 17000-18500 RPM range to avoid data scatter in this region.

5. Include smaller increments of KIS, i.e., smaller RPM changes between points to more clearly define graphed parameters. A spacing of 500 RPM between points would be suitable.

6. Allow a minimum of 3-5 minutes after recording data and setting a new operating point, for conditions to stabilize.

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